

ENVIRONMENT

NURSERY OF LIFE

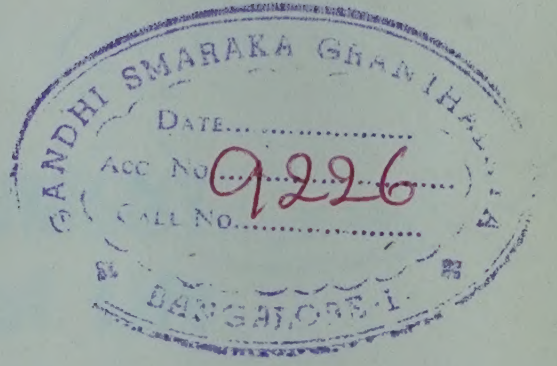


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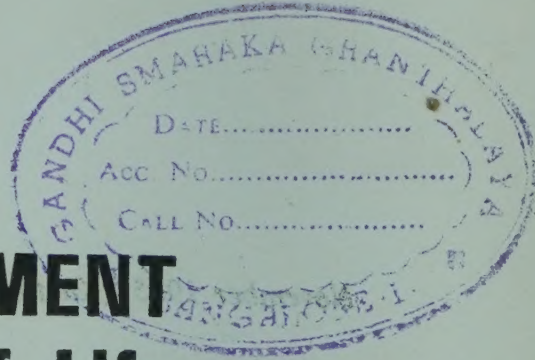
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ANJALI MOOKERJEE



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ENVIRONMENT

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About This Book

All those concerned in the sciences of evolution, both as-
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SIVATOSH MOOKERJEE

DIRECTOR

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About This Book

All along venturing on the avenues of evolution, our nation has maintained a scientific temper. With a view to popularise various scientific and technological disciplines, the Publications Division is making specific efforts to bring out a 'Series' devoted to Science and Technology for our present and coming generations.

This small volume entitled 'Environment-Nursery of Life' is the second publication in the series. The book aims to project in a simple and non-too-technical way the fundamentals involved in different aspects of environment preservation, which are so vital for human growth and development.

DIRECTOR
Publications Division
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Professor Anjali Mookerjee, who is currently Professor of Environmental Biology at the Jawaharlal Nehru University, New Delhi, read nuclear physics, for her M.Sc. from Calcutta University and later obtained Ph.D. in Biophysics from the Saha Institute of Nuclear Physics, Calcutta. She had her advanced training at the Biophysics Division of the Sloan Kettering Institute for Cancer Research, New York, and spent some time at the Rockefeller Institute, U.S.A. and later at the International Centre for Theoretical Physics, Trieste, Italy. She worked in the Division of Biophysics and also in the Division of Crystallography and Molecular Biology of the Saha Institute of Nuclear Physics. Since 1974 she has been associated with the School of Environmental Sciences, JNU, where she teaches and guides research in Radiation and Molecular Biophysics.

Preface

Why is so much noise being heard these days about Environment and what is that environmental problem which threatens our existence and brings forth a serious uncertainty for our future generations? Is it that environment did not exist before? No, it was there alright, but did not cause as much concern then to mankind. It is just like our breathing process where we constantly inhale and exhale, but are not at all aware of the process. Only when some problems arise we do realise the importance and necessity of air and the process of breathing we are performing. Likewise, environment is ever present wherever life exists. Any mismatch of life with its environment makes it apparent. Otherwise there is a harmonious unison of life and environment. One of the main causes of concern about the future of humanity is its close link with the enormous growth of the world population. Increase in per capita consumption of all the resources of our planet, corresponding growth in production output and related mounting pressure on the natural environment have created multidimensional problems. This is perhaps more so for developing countries like ours with the threat a growing population pressure exerts on the quality of life and its existence.

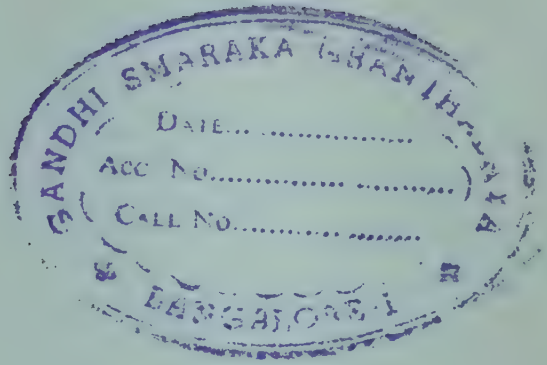
Our attempt has been to understand what we mean by environment with its wide implications. In simple terms, we may define environment as the summation of the impact and interaction of the inanimate world with the animate in which we all coexist with myriads of other living creatures. The study of the environment thus encompasses several disciplines of science.

This book aims at inculcating a new inquisitiveness in the minds of young-and if not so young, ever enthusiastic, about

the still unfolded mysteries of Nature, and the vast treasure of knowledge about the living and the non-living world acquired by humanity down the ages. It is a caution to the technological man, that inspite of his splendid success with gadgets, he must learn to handle Nature with gentle care, else the pride of his civilisation will be lost in the limbo of an unmatched cataclysm including him and other life processes. My attempt has been to make people nature-minded and act more judiciously with Nature and not against Nature. When a request came from the Publications Division, Ministry of Information and Broadcasting, Government of India, to write a booklet on 'Environment' for our 'school-college going students,...in simple and not too technical style', inspite of my busy commitments, I decided to respond positively so that some relevant facts and figures concerning environment could be brought forth to all concerned. I acknowledge my sincere thanks to the Publications Division for this opportunity. My thanks are also due to Shri Sur and Shri Sharma for the neat and expressive diagrams. Lively photographs were taken through the sensitive lens of the camera of my husband.

August 31, 1984

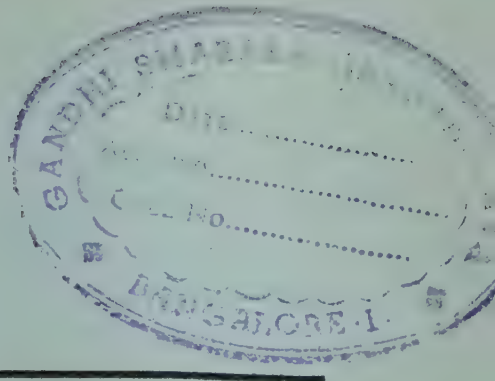
**Anjali Mookerjee
New Delhi**



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1 Environment



When dealing with environment one very frequently comes across the terms-‘ecology’ and ‘eco-systems’—which are connected with environment. Ecology is concerned with the *relationships* between plants and animals (including man) and the environment in which they live. Apparently this explanation seems very simplistic—it is not so when interrelationships and environment are seriously taken into account and explained. The total physical environment of any living organism is the *biosphere* and parts of it which are of direct and immediate importance to the organism constitute the ‘effective environment’.

‘Ecosystem is the basic *functional* unit with which we must deal since it includes both the organisms and the non-living environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth’ (E.P. Odum). The *complex* constituting the organism and the environment has now come to be known as the *ecosystem*.

Ecology then, is the study of the *interrelationships within ecosystems*. For example, the environment devoted to crop plants would then be the *agroecosystem*, where both animals and plants in the area are directly or indirectly influenced by each other. Ecosystems are not closed systems because there is always an interflow of matter and energy between adjacent ecosystems.

Physical Environment

Through the evolution of the earth Nature was endowed

with an environment which was conducive to the production of life and ultimately evolution of human life. Since that time environment may be thought of as consisting of two components—physical environment, which includes chemical, geological etc. and biological environment consisting of plants and animals which is known as the *biosphere*. The oceans, lakes, streams and rivers form the *hydrosphere* and the air envelope that completely surrounds the earth is called the *atmosphere*. (Fig. 1). The atmosphere acts as a blanket for the earth. The incoming solar radiation and outgoing radiation from the earth are affected by the atmosphere.



Fig. 1. The Biosphere composed of the lithosphere, the hydrosphere and the atmosphere.

Broadly, environment may be divided into four major elements : (1) land, (2) water, (3) air and (4) living organisms. Light, temperature and water in the form of rain, are

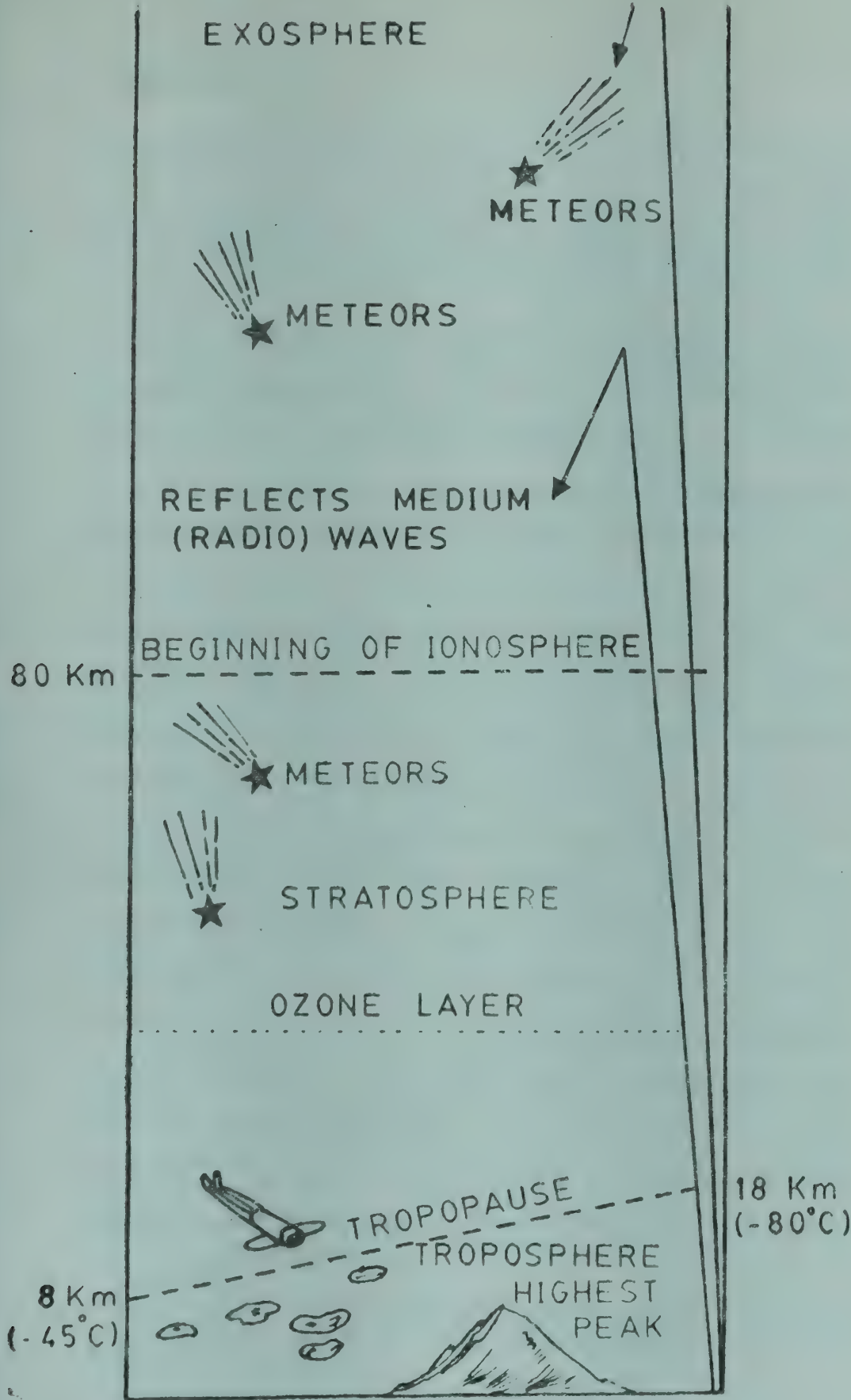


Fig. 2. The atmosphere with its different components.

ecologically important environment factors on land ; light, temprature and salinity are the big three in the sea. In fresh water, other factors, such as oxygen, are of major importance. The composition of the atmosphere is very important as the weather and climate of any place is dependent on it.

There are four distinct layers in the atmosphere, the lowest being *troposphere*, then *stratosphere* and over that *ionosphere*. (The uppermost layer is known as the *exosphere* whose denisty is very low.) The tropopause separates the stratosphere from the troposphere (Fig. 2).

IONOSPHERE : The term ionosphere applies to that part of the earth's atmosphere which extends out 60 kilometers above the globe.

Consisting of several layers of ionised air the ionosphere repeatedly reflects short radio waves, making possible radio-communication over long distances. Ultraviolet radiation forms ozone in the atmosphere, a gas which reaches maximum concentration at an altitude of about 30 km. Ozone serves as a screen that protects the earth's surface from excessive ultraviolet radiation, which is harmful to all living things.

These unstable forms of solar radiation affect the entire structure of the atmosphere's upper regions. Related with these are magnetic storms, the polar auroras, disturbances in radio communication and other phenomena. The lower regions of the atmosphere also are, directly or indirectly, affected by these solar radiations which, in turn, may affect the condition of living beings.

STRATOSPHERE : This is the region of the atmosphere which is free from clouds and the related weather activity. Hence, it provides ideal flying conditions for large and powerful aircrafts. The thickness is about 50—55 km and consists of a rich layer of ozone. This ozone layer absorbs the shorter harmful ultraviolet radiation from the sun.

TROPOSPHERE : The troposphere is the region of the atmosphere extending from the surface of the earth upto

height of 8 to 10 kilometers at polar latitudes, 10 to 12 kilometres at the moderate latitudes, and up to 16 or 18 kilometres at the equator.

In the troposphere, the percentage of different gasses in the air does not vary with height, remaining practically the same as it is at the surface. The only exception is the water-vapour content which is mainly dependent on the weather conditions and sharply decreases with height.

The most important property of the troposphere is that its temperature decreases with height. The average vertical temperature gradient of the troposphere is 6 degrees per kilometre (about 5 degrees per kilometre in the lower troposphere and 7 degrees per kilometre in the upper troposphers). The annual average temperature of the air in the upper troposphere is -55°C in the polar regions, and -80°C at the equator. The upper boundary of the troposphere is called the tropopause which is a narrow region of constant temperature.

The cause of the gradual decrease in the temperature of air with height lies in the fact that the troposphere is almost transparent to sun rays which, on passing through it, heat it very little, if at all. The bulk of the solar energy is absorbed by the earth's surface. The heated earth surface is, in turn, a source of thermal radiation which heats the troposphere in an upward direction. Convective air movements also contribute to the heating of the troposphere—the air adjacent to the ground rises in temperature and moves upwards to give way to a colder air which is in turn heated and moves upwards, and so on. The non-uniform heating of ground areas produces ascending and descending air currents which result in turbulences and the mixing of air masses vertically, and this decides the temperature conditions in the troposphere.

Although the troposphere extends out to a relatively low height, it accounts for four-fifths of the entire air mass. The average pressure at the earth's surface is 1014 millibars (1 millibar = $1/1000\text{th}$ per. 1 bar = 105 newtons per square

metre = 1.019 kilograms per square centimetre which is very close to one atmosphere. 1 millimetre Hg = 1.332 millibars). At an altitude of 5 kilometres, it is nearly halved, at 11 kilometres it is 225 millibars, while at an altitude of 17 kilometres (the upper boundary of the troposphere at the equator), the atmospheric pressure is a mere 90 millibars.

The water vapour contained in the troposphere comes from the evaporation of water (likewise due to solar radiation) from the surface of the oceans, seas and water reservoirs. This is why the troposphere over an ocean carries more moisture than it does over a desert. The water-vapour content rapidly decreases with height. At an altitude of 1.5 kilometres, the water-vapour content is about one-half and at the upper boundary of the troposphere it is a few thousandths of what it is at the earth's surface.

The key characteristics of the troposphere are pressure P (in millibars), absolute temperature T (in degrees Kelvin, such that $T = t^{\circ}\text{C} + 273$), and absolute humidity a (also in millibars). Sometimes, the water-vapour content of air is expressed in terms of specific humidity S (which is the mass of water vapour in grams per kilogram of air, or relative humidity r , expressed in per cent.

Absolute humidity a is related to S and r as follows :

$$a = \frac{S_{g/kg} \cdot P_{mb}}{623 - 0.377 S_{g/kg}} \text{ mb}$$

and

$$a = \frac{E_{r(mb)} \cdot r}{100} \text{ mb}$$

where E_x is the pressure, found from charts, or water vapour which will saturate the air at a given temperature.

THE LITHOSPHERE : The solid body of the earth, the lithosphere began to take shape several (5 to 6) billion years ago, primarily under the influence of the forces of gravitation. Its present structure came about as a result of the operation of the forces of gravitation of the earth's mass itself and its

rotation, of the tidal movement of the seas which again is due to the gravitation exerted by the moon and the sun; also due to heat emanation generated by radioactive fission. These changes in the lithosphere are continuous processes including changes in its constituent elements and slow processes like continental drift, mountain formation, etc. The results become evident after a lapse of hundred of thousands or millions of years. The understanding of the environment and ecology at the present calls forth a variety of disciplines like physics, chemistry, mathematics, meteorology, climatology, geology, geography and of course, biology. A very important and essential feature of these studies is concerned with energy transformations occurring within ecosystems. The main source of energy of all the natural and many of the anthropogenic processes in the biosphere is solar radiation, which reaches the earth in the form of visible light and infrared radiation. This sufficiently stable stream brings to the upper limits of the earth's atmosphere 1.92 calories per square centimetre every minute (which gives a power of 6×10^3 kw). The clouds that cover 70 per cent of the earth's surface reflect about 50-60 per cent of this radiation back into outer space. A comparatively small part of solar radiation is absorbed by the atmosphere, which gets heated in the process while the remaining radiation reaches the earth's surface. There is surface reflection also from different constituents: from snow 80%, the ocean 15%, the soil, forests and other elements 20-30% and the earth's surface as a whole about 35 per cent. The rest of the radiation is absorbed. This absorption is accompanied by the heating of the land and the ocean and all objects on their surface. It is also accompanied by photosynthesis in plants (Fig. 3), which is ultimately responsible for the formation of the entire biomass on our planet, by evaporation of moisture, and many other phenomena. The heat which is given off by the surface of the earth is transmitted in a variety of ways to the atmosphere.

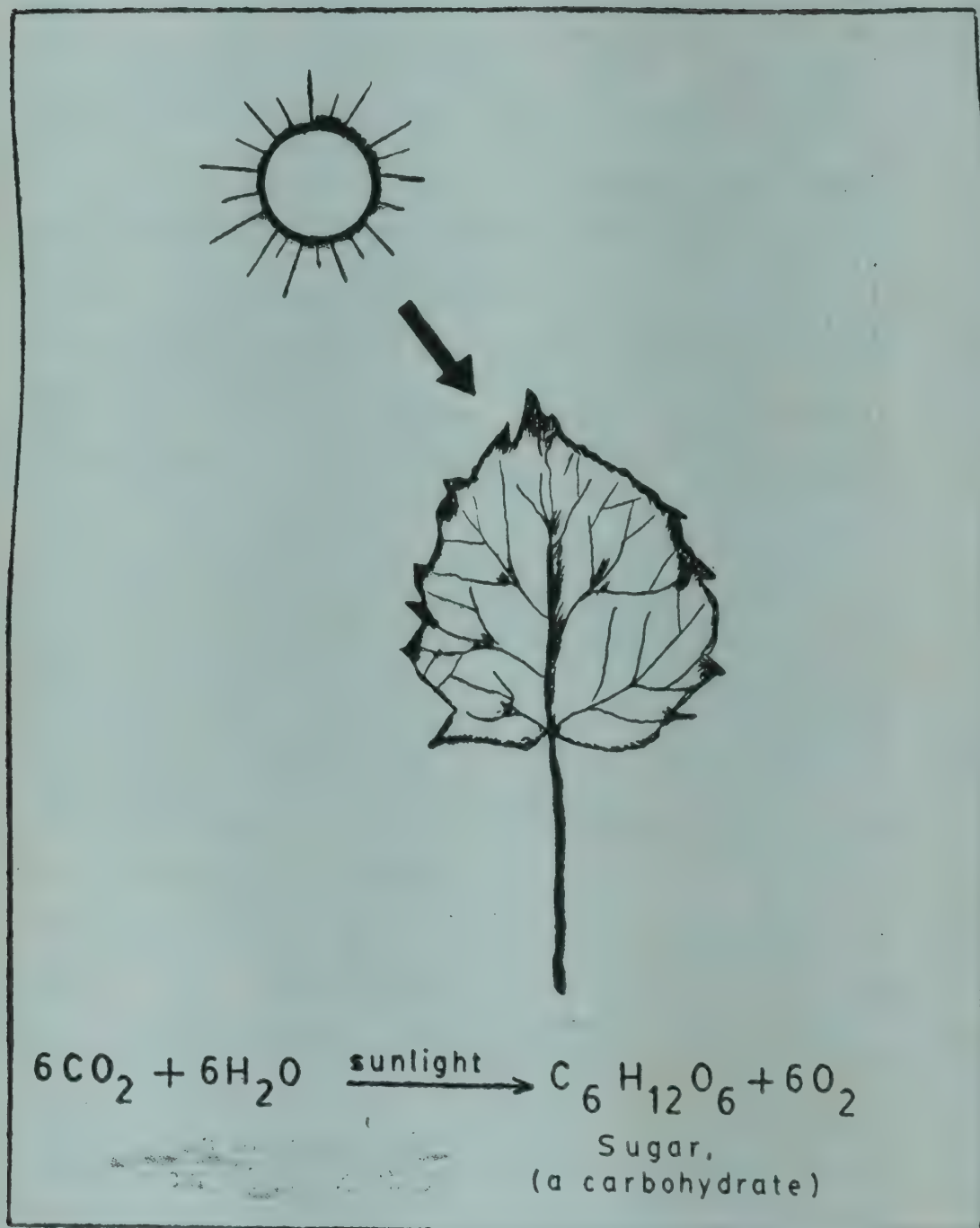


Fig. 3. Photosynthesis.



A bamboo bridge across a gushing rivulet.



A riot of colours.



Bright blooms.

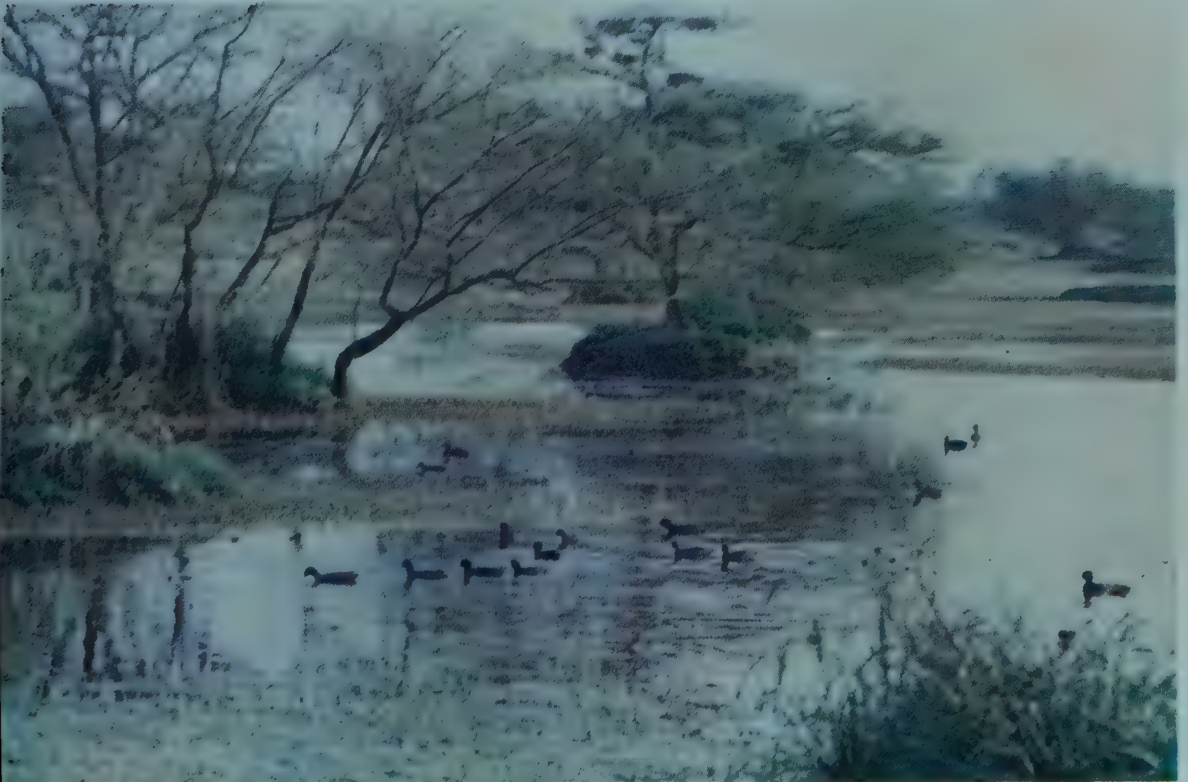


The roadside sentinels.



*Ghana bird sanctuary, Bharatpur (Rajasthan)
migratory storks ready for nesting.*

*Ducks in Ghana sanctuary. In the
background some nests are seen on
tree-tops.*





A forest is a community of living beings among whom the tree is the biggest.



The lotus.



Apple—the most delicious hill fruit.

The difference in solar heat between the tropics and the polar regions, between the oceans and the land, creates the circulation of the atmosphere. Roughly the cycle is like the following: air in the tropics is heated, rises high above the earth's surface, and flows into the cold polar regions, where it cools off and descends. The reverse movement, in the lower regions of the atmosphere back towards the equator is much more complicated because of the deflecting effects of the earth's rotation as well as the existence of mountain ranges (like the Himalayas). There are special subsystems of atmospheric circulation between land and ocean.

The different feed-back mechanisms that are involved in this kind of circulation are as follows: clouds form due to evaporation over a heated region and screen that region from further solar radiation. The sun-warmed waters of the ocean are transferred by currents to its different parts, thus creating new sources of heat, etc.

At the same time the entire system of atmospheric circulation maintains a certain mobile, yet stable equilibrium. This can be judged from the stability of climate in any part of the world. Recurring atmospheric fluctuations around this fixed 'normal' pattern of circulation are regarded as changes in weather.

Meteorological events are extremely powerful. The movement of air masses determining the weather over a territory about one thousand kilometers in diameter and lasting several days, has a power of hundreds of millions of kilowatts.

An important element of atmospheric circulation is the circulation of moisture. About 4,50,000 cu km of water evaporates from the surface of the world ocean every year, out of which more than 3,00,000 cu km precipitates back into the ocean. The remaining 150,000 cu km precipitates over the continents and feeds rivers.

TABLE I. *Characterization of Moisture circulation at any given movement*

	Cubic kilometres
Atmosphere	14,000
All the rivers	1,200
The Lakes	280,000
All living organisms	10,000
The Oceans	1400,000
Glaciers	24,000

The organisation of the Biosphere

Life and the physical environment go together, for the environment supplies both the nutrients and the conditions necessary for the existence of life. This combination of living things and the environment in which life exists is the biosphere. The biosphere extends up into the atmosphere to more than 10,000 metres, down into the ocean to a depth of approximately 8000 metres, and more than 250 metres below land surfaces.

Most forms of life are adapted to a particular environment that is restricted in general living conditions and food resources. Moreover, the nutrition of any species must be in balance with the biosphere as a whole. Thus, the biosphere is a global biological system based on a continuous, or cyclic, flow of energy and nutrients.

At the present time, earth, among all the planets of our solar system, is the most favourable for the production and survival of life. Its distance from the sun, neither too close nor too far, creates an environment that permits the various biochemical and biophysical reactions on which life, as we know it, depends. Environment includes all factors external to the organism that in some way affect it.

BIOLOGICAL ASPECTS: Certain features of climate and terrain, the conditions of surface water and soil determine the biogeoceneosis of every region of the world. On the other hand,

the association of living organisms, the biota (flora and fauna), if viewed over long periods of geological time, plays a part in creating rock and soil, alters the composition of the atmosphere and hydrosphere, and affects the climate and structure of the planet's biosphere. In the process of photosynthesis solar energy and substances on the earth's surface yield about 180 billion tons of vegetable biomass (dry weight) and about 300 billion tons of oxygen. The plants absorb and evaporate about 30,000 cu km of water, which is about 50 per cent of the entire water evaporating from the land surface. Most of the solar energy absorbed by plants is expended in transpiration and only a small percentage of it in photosynthesis.

The biomass provides food for the entire animal world including humans. The oxygen produced by plants makes up for that removed from the atmosphere by the living organisms which breathe it (except for anaerobic organisms which constitute a negligible part of life on earth), and also that used up in the processes of oxidation in the inanimate world.

TABLE II. *A rough estimate of the relative contribution of the basic elements of the biosphere to the creation of the biomass*

Elements of biosphere	Total surface area in sq. km	Percentage
World Ocean	360 million	43%
Tropical forests	10 million	29%
Meadows and Grassland	42 million	10%
Forests of temperate zone	25 million	10%
Farmland	14 million	8%

The top regions of the biosphere—the higher layers of the atmosphere that gradually merge into near space—have but very little matter. The photochemical and electromagnetic processes taking place in this zone consume negligible amount

of energy compared to the forces operating in the terrestrial regions of the biosphere. Nevertheless, these processes have their own importance. We have already seen that the earth receives bulk of the solar energy as visible light and in the near regions of the infrared range (Fig. 4). A relatively

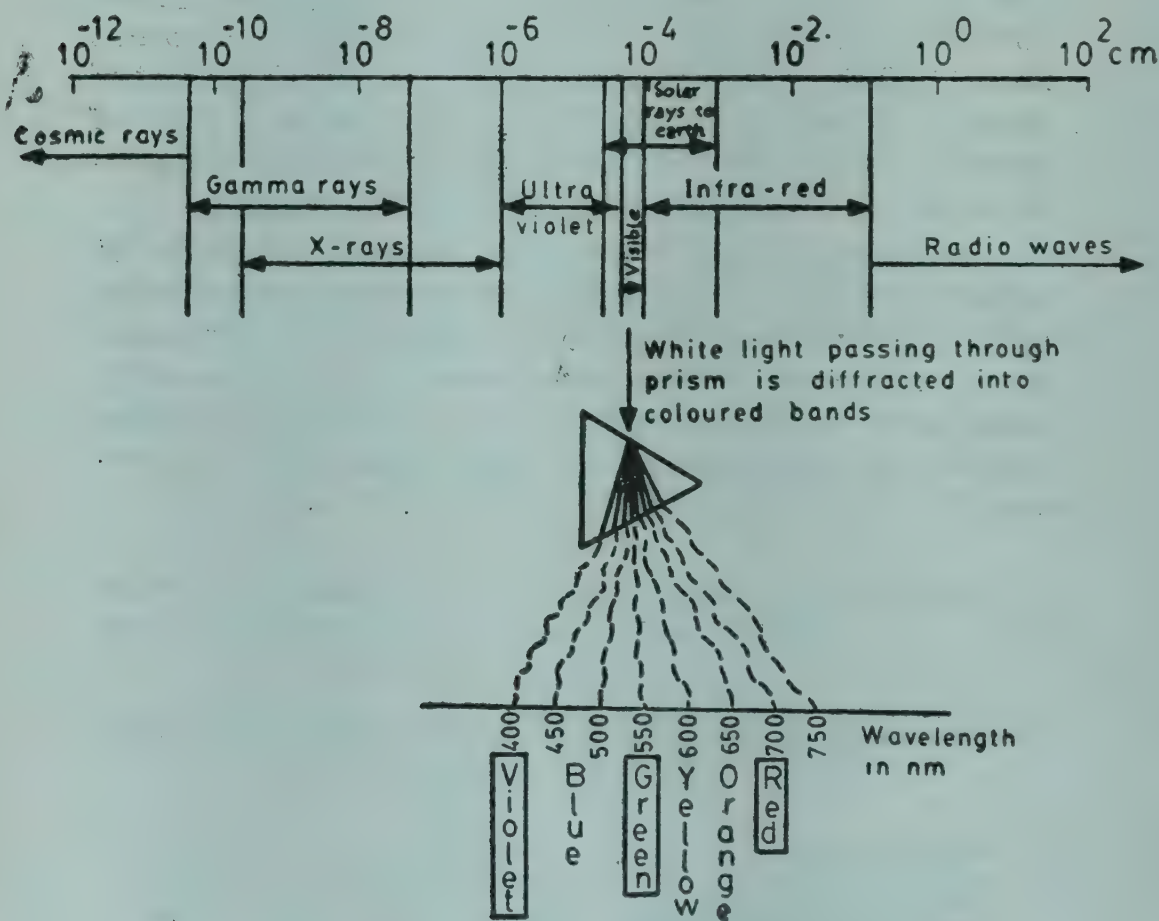


Fig. 4. Spectra of electromagnetic radiation.

insignificant part of the solar energy falls as ultraviolet, X-ray and gamma-ray radiation and the streams of atoms and atomic particles. Unlike visible light, this part of the stream of solar energy is largely the result of various phenomena known by the collective term 'solar activity', which includes

the formation of sun spots protruberances and other processes.

Due to the presence of the magnetic field of the earth some of these charged atomic particles do not reach the earth's surface but are arrested and accumulated in the so-called radiation belts (Van Allen). Others cause ionisation of the atmosphere at different altitudes.

SOCIAL ASPECTS : Many people think that ecology is synonymous with pollution or the conservation of rare animals. It is only recently that we have come to realise the actual problems related to environment and become concerned about trends in the growth of the human population and the consumption of natural resources. To realize and to deal with these problems one has to have a thorough understanding of the interdependency of all living beings and the natural environment. For the underdeveloped countries these are the main problems from which other problems stem. For example, when a dam is going to be constructed one has to plan before hand about the supply of fuel to the thousands of labour who would stay at the site. If they are not supplied with fuel their alternate source will be wood from the surrounding forest which will ultimately lead to soil erosion and more silting of the river. This again would directly affect the fauna (fish) and flora of the region as well as the daily life of the surrounding villagers. Judicious management and planning is very important when some new developmental activity is undertaken.

In industrial countries the most important event has been the realization and demonstration that pollution resulting from industry and agriculture is harmful to people and to the surroundings in which people live. Industrial pollution comes from waste products of the manufacturing and service industries and the agricultural pollution results from the accumulation of toxic chemicals derived from pesticides and fertilizers.

There are two ways of designating environment : The micro--and the macro-environment. Very intimate, local and immediate surrounding of the organism is known as the micro-environment. The macro-environment is sum total of the physical and the biotic conditions existing external to the organism and its micro-environment.

2

Profiles of Ecology and Ecosystems

The field of ecology is varied and there are levels of organisation. There exists a 'biological spectrum' such as protoplasm, cells, tissues, organs, organ systems, organisms, populations, communities, ecosystems and the biosphere. Ecology covers largely the latter four levels. The term population in ecology originally used to denote a group of people, is broadened to include groups of individuals of any one kind of organism. In the same way, community in the ecological sense includes all of a population of a given area.

Ecosystems as ecological units

The biosphere is made up of ecological units called



Fig 5. A pond ecosystem.

ecosystems. Groups of individuals having similar properties and living in the same area are called *populations*. When various populations interact with one another, they form a *community*. The interactions of such a community and its physical environment constitute an *ecosystem*. An ecosystem, then, refers to the organisms in the system and to the physical environment that supports their life (Fig. 5).

The living members of an ecosystem can be divided into three categories, depending on their role in maintaining the stable ecosystem : *producers*, *consumers* and *decomposers*.

Photosynthesizers, such as the cyanobacteria and purple and green bacteria, microscopic algae, and large plants, function as the producers of organic compound from inorganic materials. Such forms of life are called autotrophs. The consumer category is made up of heterotrophs, species that cannot produce organic substances from inorganic ones. Microbial consumers are mostly protozoans. The microbial decomposers are various bacteria and fungi that break down complex organic products such as the remains of animals, plants and other microbes into smaller compounds into inorganic materials that can be used by plants for their producer activity. In short, these microorganisms are microscopic "recycling centres". It would be difficult for life to continue normally without them.

Decomposers function in the ecosystem by using rotting organic matter as nutrients. Like consumers, these saprophytic organisms are heterotrophic. They secrete a variety of extracellular enzymes such as proteases, carbohydrases, and lipases, which render the waste materials, on which they act, soluble, so that they and other organisms can utilize them for food. Subsequent metabolic activities by these organisms further decompose the wastes and return their essential elements to forms that can be used in the nutrition of plants and other organisms.

The activities of producers, consumers and decomposers together constitute members of food chains. These are circular processes that promote the exchange of nutrients and energy flow in the ecosystem. Appropriate analysis would reveal an interconnection of the different animals together as a community. This brings about a stratification of the community on the basis of their mode of food capture. It can easily be understood from a study of the relationship of organisms of a community to the food web in a particular environment. Trophic level is the term applied to such relationships on the basis of food, and through successive trophic levels the primary stock of energy as obtained by green plants is continually circulated. The chain or sequence of events in which the herbivores consume plants, carnivores feed on the herbivores (and saprophytes feed on all organisms) constitute the food chain (Fig. 6).

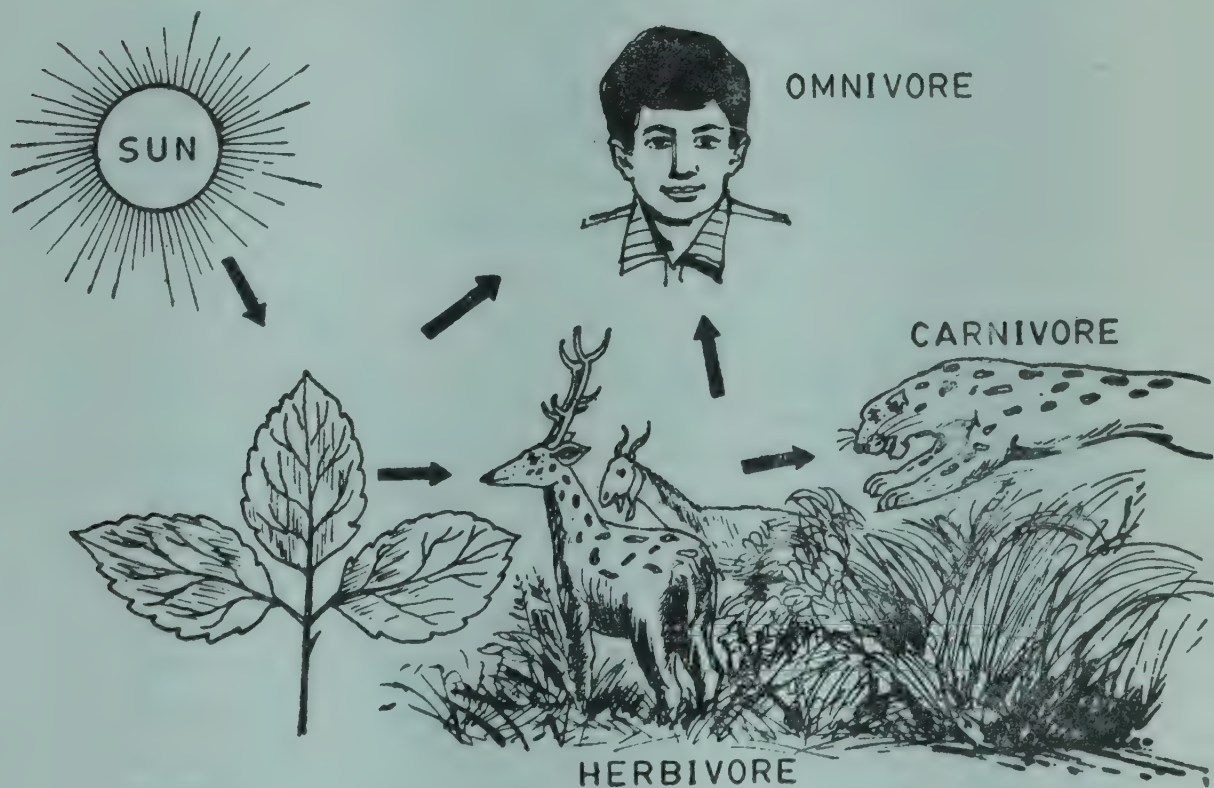


Fig. 6. The food-chain with man as consumer of both herbs and meat.

COMPONENTS OF AN ECOSYSTEM : To an ecologist the species is his fundamental unit and the environment generally harbours more than one animal or plant species or species populations. Ecological observations may deal with the study of individual organisms or species in relation to their habitat (autecology, or the study of associations of organisms in relation to a particular area or biotope or habitat (synecology). While synecology is the ecology of the biotic community, demecology refers to the ecology of populations. In autecological studies the assessment of the intrinsic capacities of organisms which enable them to cope with environmental conditions is important. The term ecological valency has been used to refer to the adaptive range of both the individual and the species. An assemblage of populations inhabiting an area possessing some uniformity in physical feature and vegetation constitutes the community. While a population is formed of a number of animals and plants inhabiting an area, a community is an aggregate of several species of plant and animal population—the biotic community which forms a distinct ecological unit. Communities differ according to the environment and the nature of the community is an index of the environmental conditions.

The place that an animal occupies in a biotic community which expresses its functional status, is called the *niche*. According to Grinnell the open scrub and grassland is the niche for one type of deer, the blackbuck ; again, the open forest with glades is the Chital niche, and the thicker forest in hilly terrain the sambar niche. But according to some other workers in this field the term niche is used mainly to denote the role or function of a species in its ecosystem. For example the Chital niche represents its function as a major consumer of grasses and as the major prey of the larger predators. The niche may be better defined as the place that an animal occupies in a biotic community in relation to its food and enemies. It results from the animal's peculiar structural adaptations, physiological adjustments and special behaviour

patterns. Every animal exhibits a specificity with regard to its niche and no two animals can occupy the same niche permanently for a long time in the same locality. The concept of niche is often difficult to define, since it includes an organism's habits relationships to other forms of life, food-related reactions and ability to change or be changed by its environment. Thus, certain plants produce food for community, while other forms of life have the role of decomposer and, at times, predator. An invasion of an organism's niche by another form of life results in competition and ends in one species being eliminated. The term *habitat* means the place where the organism lives. It is the address and niche is the profession, (Fig. 7a).

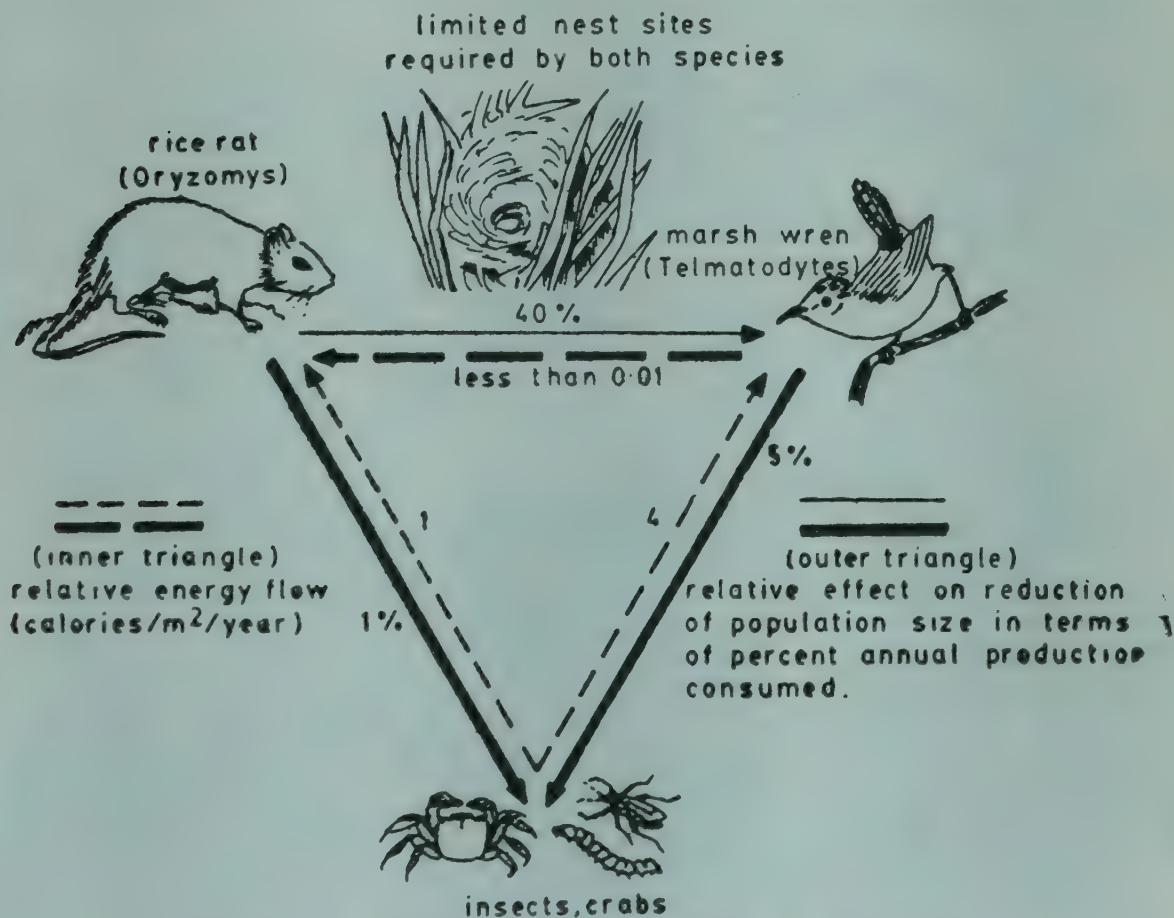


Fig. 7. (a) A predator-prey triangle in a marsh ecosystem.

COMMON MAN-CATTLE-TIGER HABITAT—AN EXAMPLE : The state wildlife authorities of Madhya Pradesh pay about Rs. 2 lakhs a year in compensation to the people who lose their cattle to tigers in the Umaria forest division of Shadol district. This gives an indication of the menace of cattle lifting big cats in the area, with the highest density of tiger population in Madhya Pradesh. The Umaria forest tract, with rich grassland, has been the homeland of wealthy cattle owners for generations. They apparently consider the loss of cattle to tigers as quite small a price for the abundance of fresh cattle feed and the flourishing trade in dairy produce. Thus, Umaria provides a common habitat for man, cattle and tiger (Fig. 7b).



Fig. 7. (b) *A man-cattle-tiger habitat.*

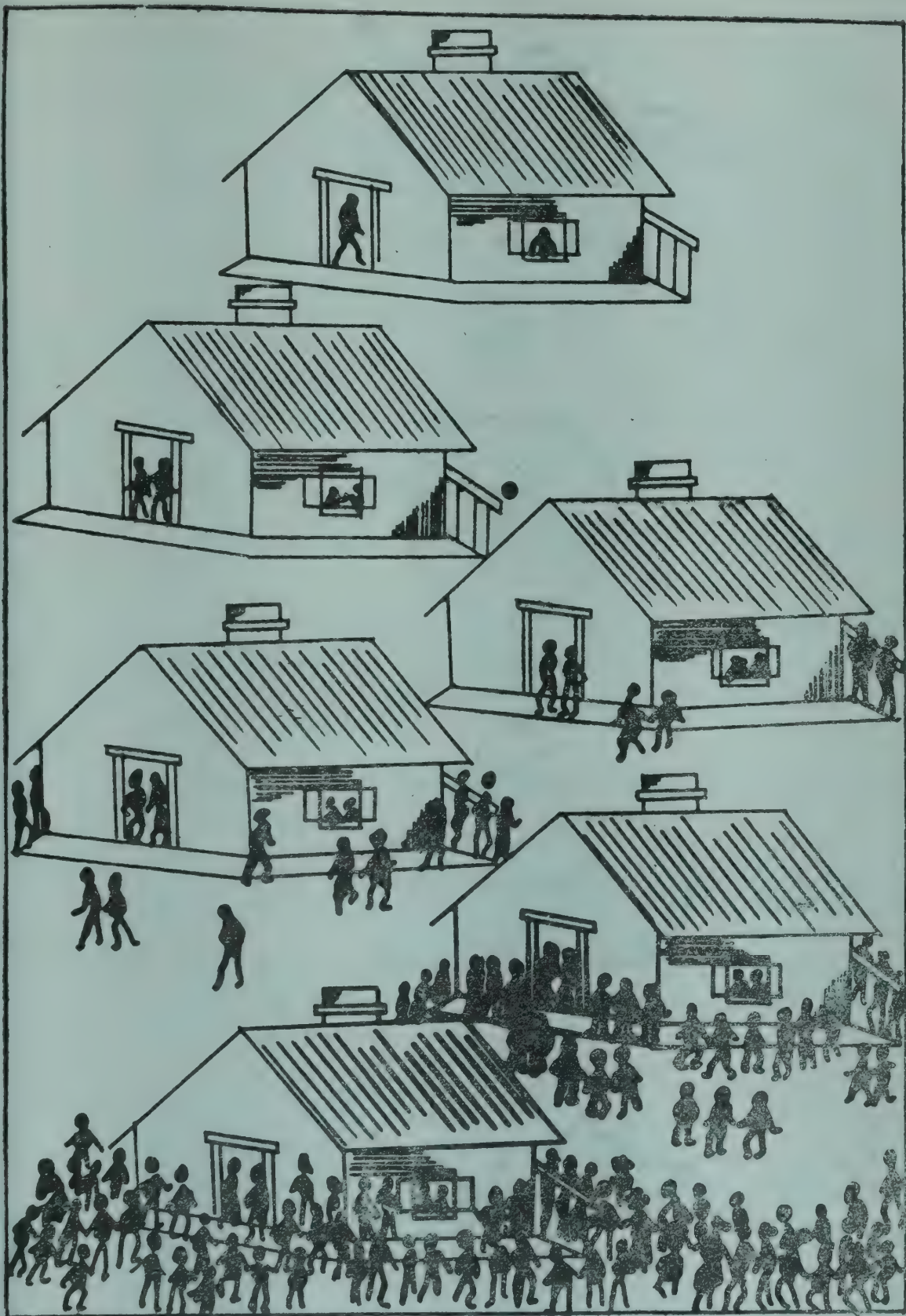
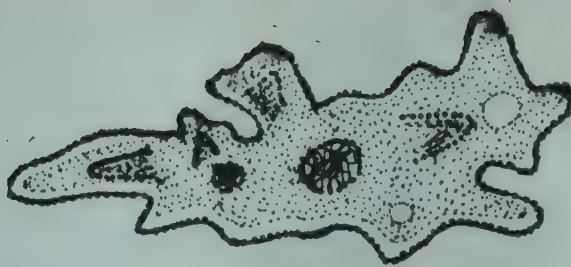
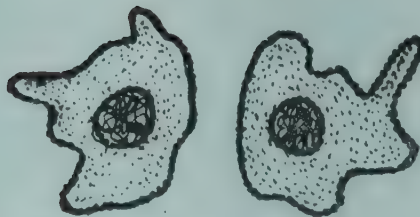
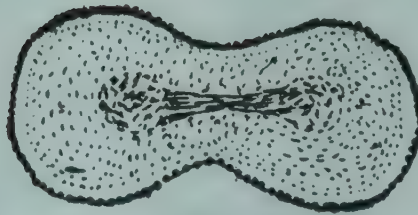
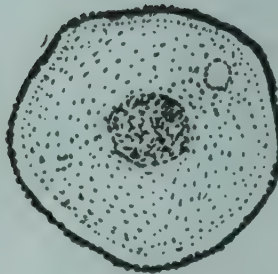


Fig. 8. When population density increases available space per person decreases



AMOEBA CELL



DAUGHTER CELLS

Fig. 9. The unicellular organism amoeba divides into two daughter cells. Each of these two cells will again divide into two-hence total number becomes four, and so on.

POPULATION: The word population is from the Latin *populus* which means people and for all purposes meant human numbers. But now a days, according to ecologists a population is defined as the collective group of organisms of a particular kind in the community. Roses growing in a garden during the winter constitute a population. In practice a population is composed of all the organisms of the same species found occupying a given space. Some of the more important population characteristics or group attributes (which are neither shared by individuals in the population nor by the community) are the following :

Density : Population size in relation to a unit of space (Fig. 8).

Birth rate or *natality*—that is the rate at which new individuals are added to the population by reproduction (Fig. 9). Death rate or *mortality*—the rate at which the individuals are lost due to death (Fig. 10a+10b).

Age distribution—the proportion of individuals of different ages in the group.

Population dispersion—the way in which individuals are distribution in space.

Population growth rate or growth form—the net result of natality, mortality and dispersal (immigration and emigration) from the group.

Individual organisms have birth and death, they grow and age but such characteristics as *birth rate*, *death rate*, *density*, *etc.* as listed above are of any value and meaning only at the group level. If one is to understand thoroughly the ecology of a species one has to study and measure these population group characteristics as well as know the life history and identifying features of the species.

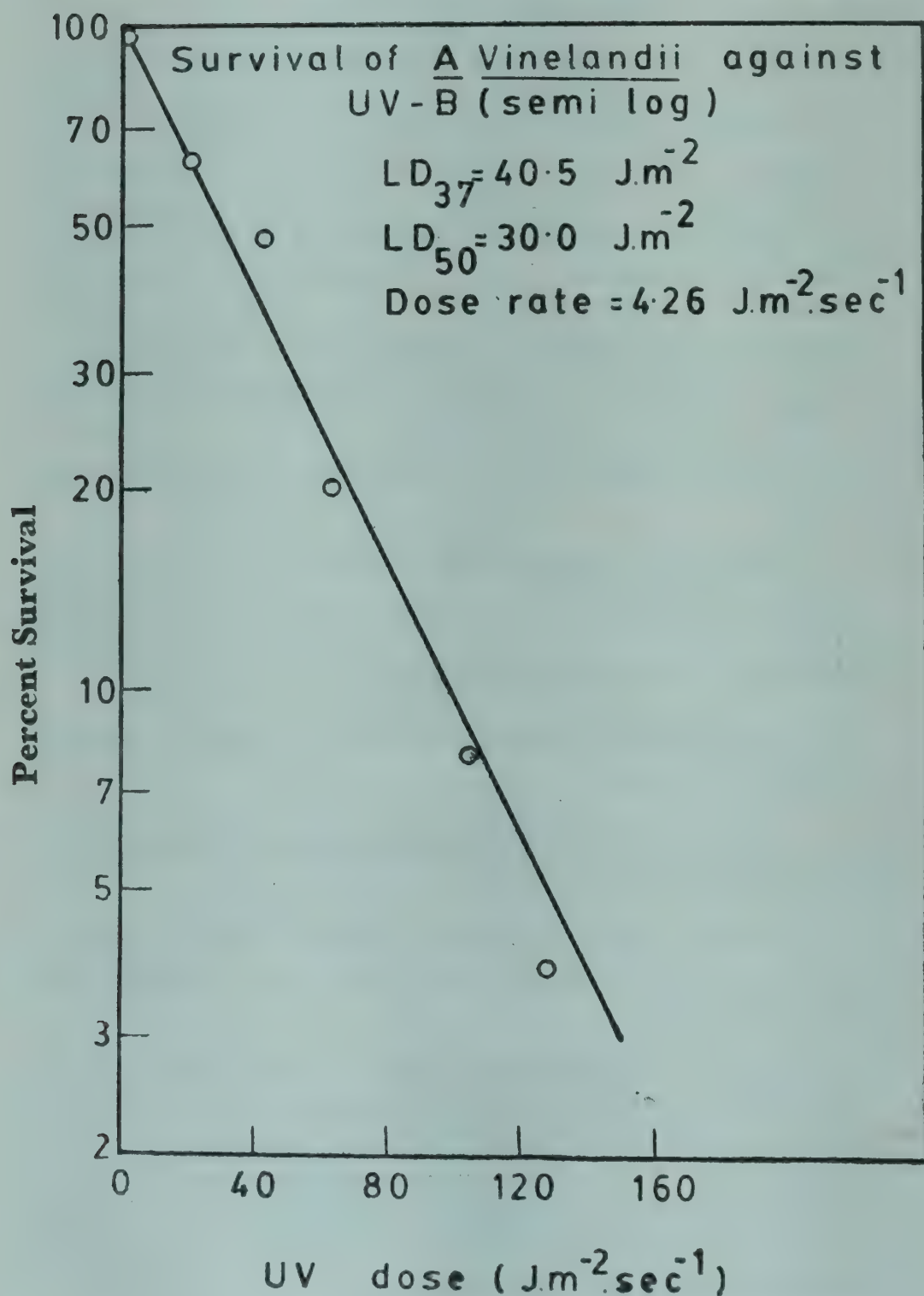


Fig. 10. (a) A linear survival curve (100—percent survival=percent dead) due to ultraviolet radiation of a population of bacteria.

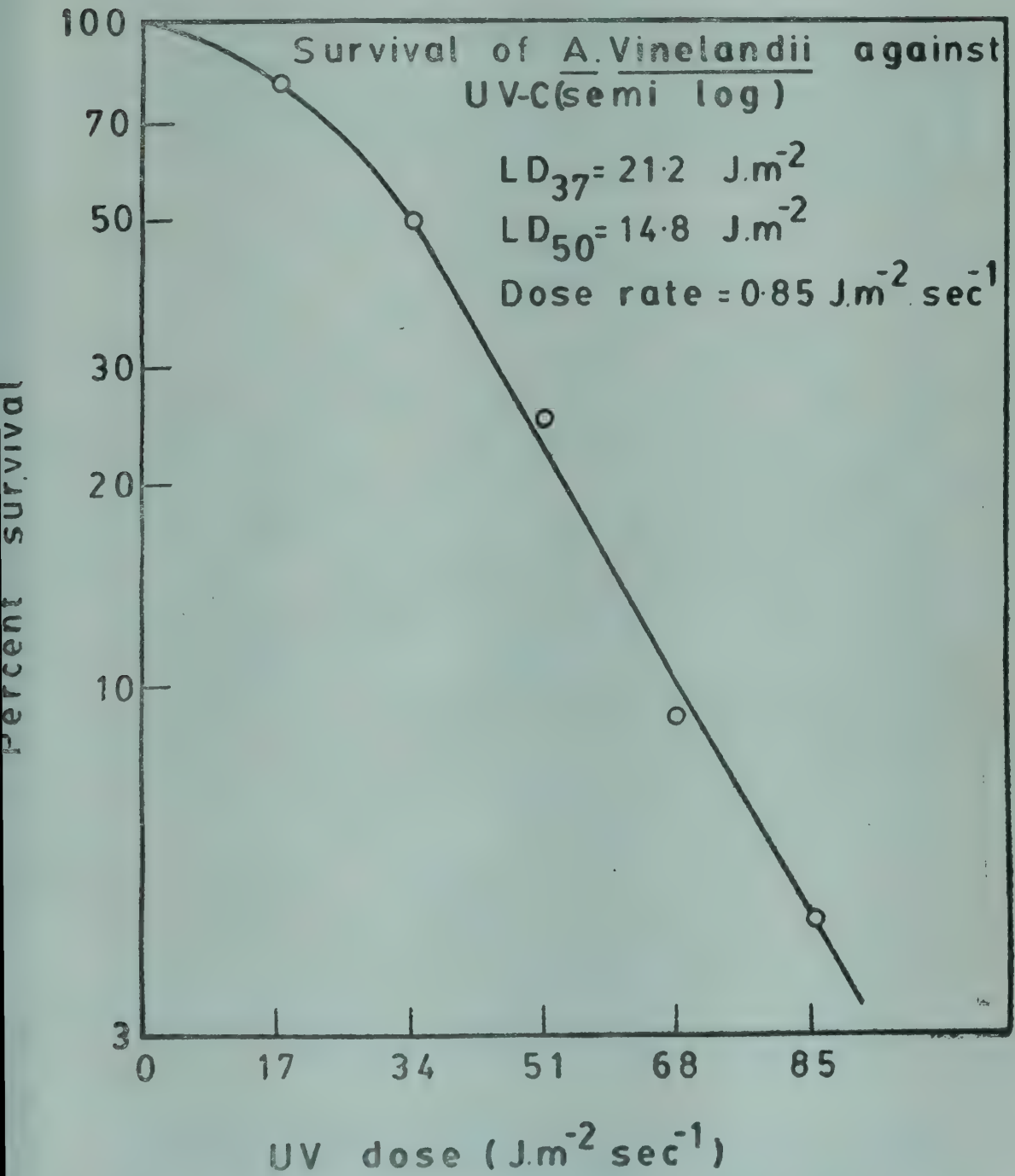


Fig. 10. (b) A similar curve with an initial shoulder showing that initially the population was resistant to lower doses of radiation. Further radiation overcomes the resistance.

It is quite clear that the degree of crowding or density and the dispersion pattern of individuals (i.e. random, uniform, or clumped together in a limited area) are specially important in determining the degree of interaction between individuals of the same or other species (Fig. 11).

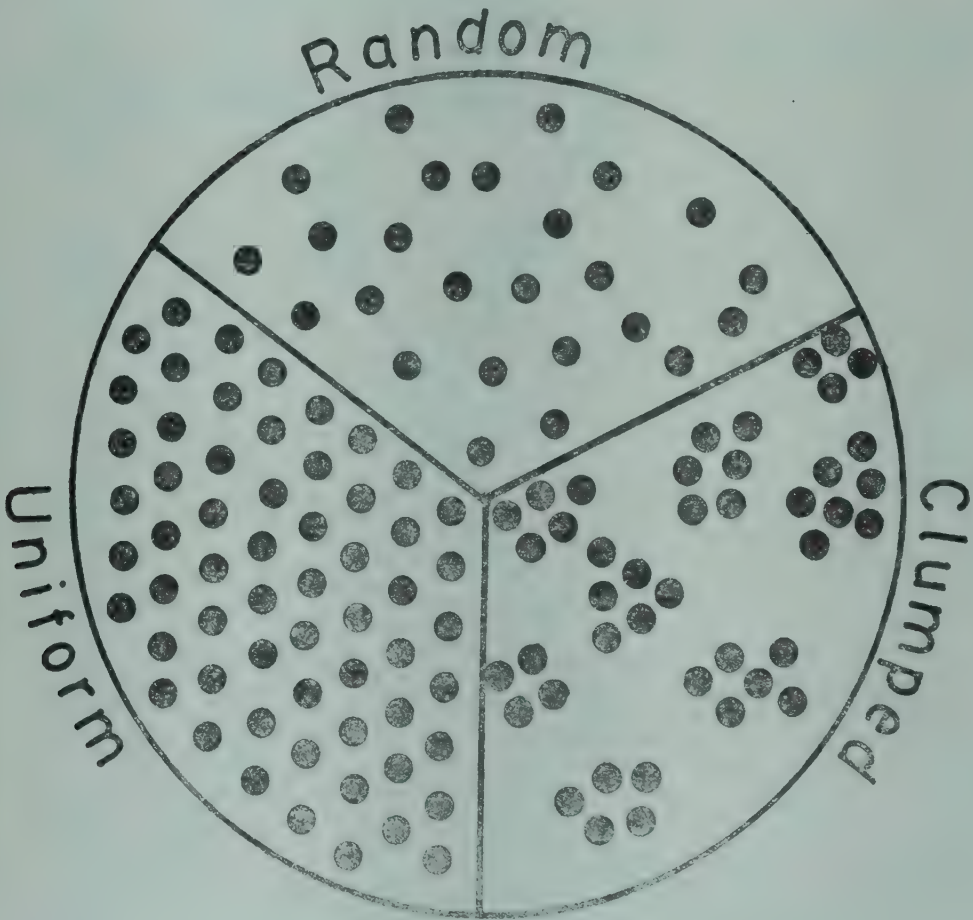


Fig. 11. Different types of distribution of population.

These are three patterns of population growth rate in relation to population density (Fig. 12).

- (a) The growth rate decreases as density increases.
- (b) Growth rate remains high until density become high

and factors outside of the population become limiting.

(c) Growth rate is highest at intermediate densities.

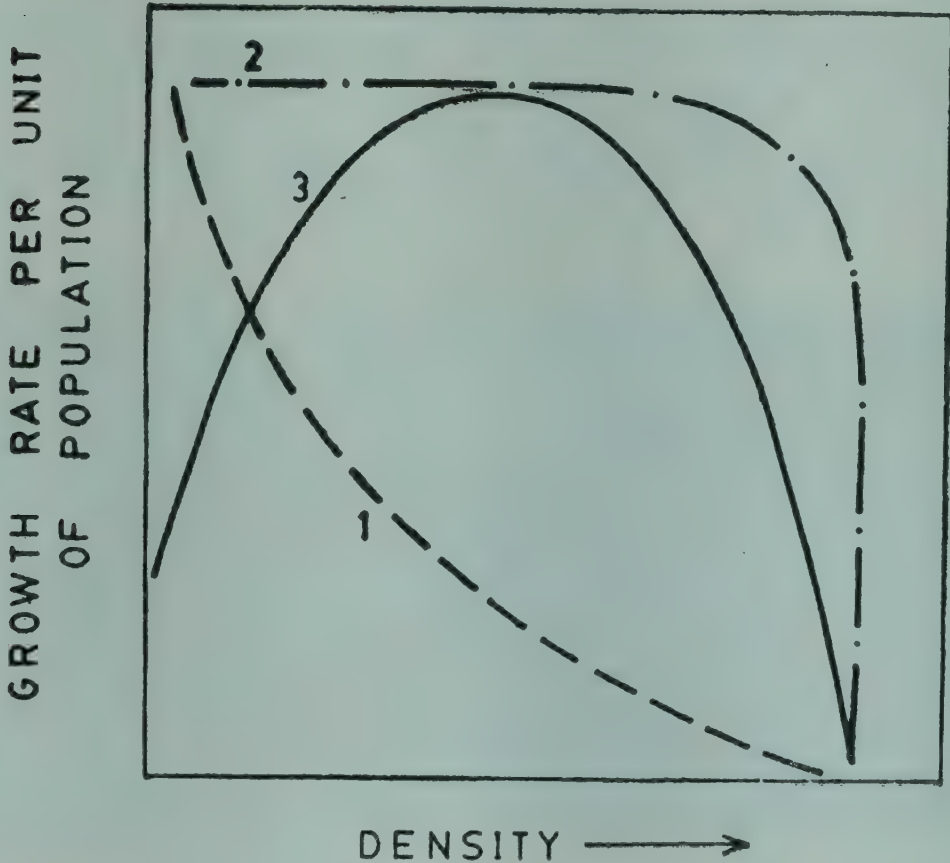


Fig. 12. Three patterns of population growth in relation to population density. (1) decrease in growth when density increases, (2) growth rate remains high until density becomes high and factors outside of the population become limiting, (3) growth rate is highest at intermediate densities.

EXPONENTIAL GROWTH : Exponential growth is different from a linear growth. For example, if one wants to save money but not in the bank—then one sets aside a sum, say, Rs. 100/- every year. Every year one adds Rs. 100/- more and at the end of ten years the total saving will be Rs. 1000/-. Now if one puts the money in the bank—Rs. 100/- every

year—at an interest rate of 7 per cent—and one leaves the amount invested plus the interest added to it the total amount becomes Rs. 1400/- after ten years. The same kind of event can occur in a population of organisms.

Suppose there is a pond which has a population of lotuses which doubles every day. After 30 days the whole pond is covered. Which means that even on the 29th day half of the pond was empty (Fig. 13). This indicates how an exponential process seems at first to be unimportant and it is only

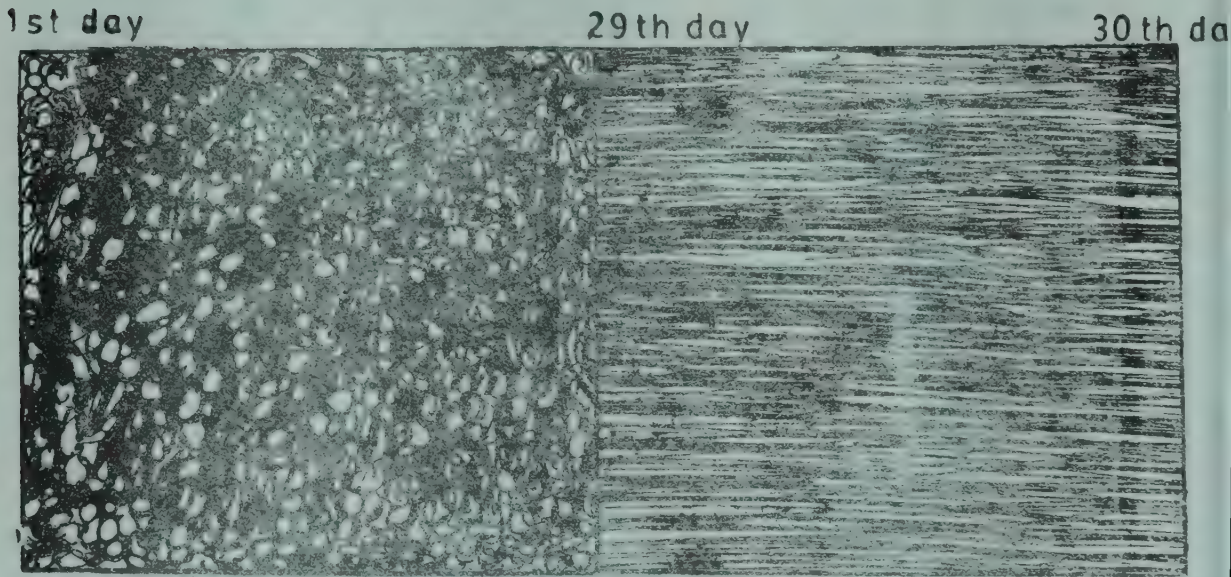


Fig. 13. Pond with flowers (depicting exponential growth)

later that its effect becomes conspicuous. A bacterial or yeast cell population will grow exponentially if the nutrient or sugar supply is unlimited. If there is limited supply then a static condition is obtained after the exponential rise. (Fig. 14).

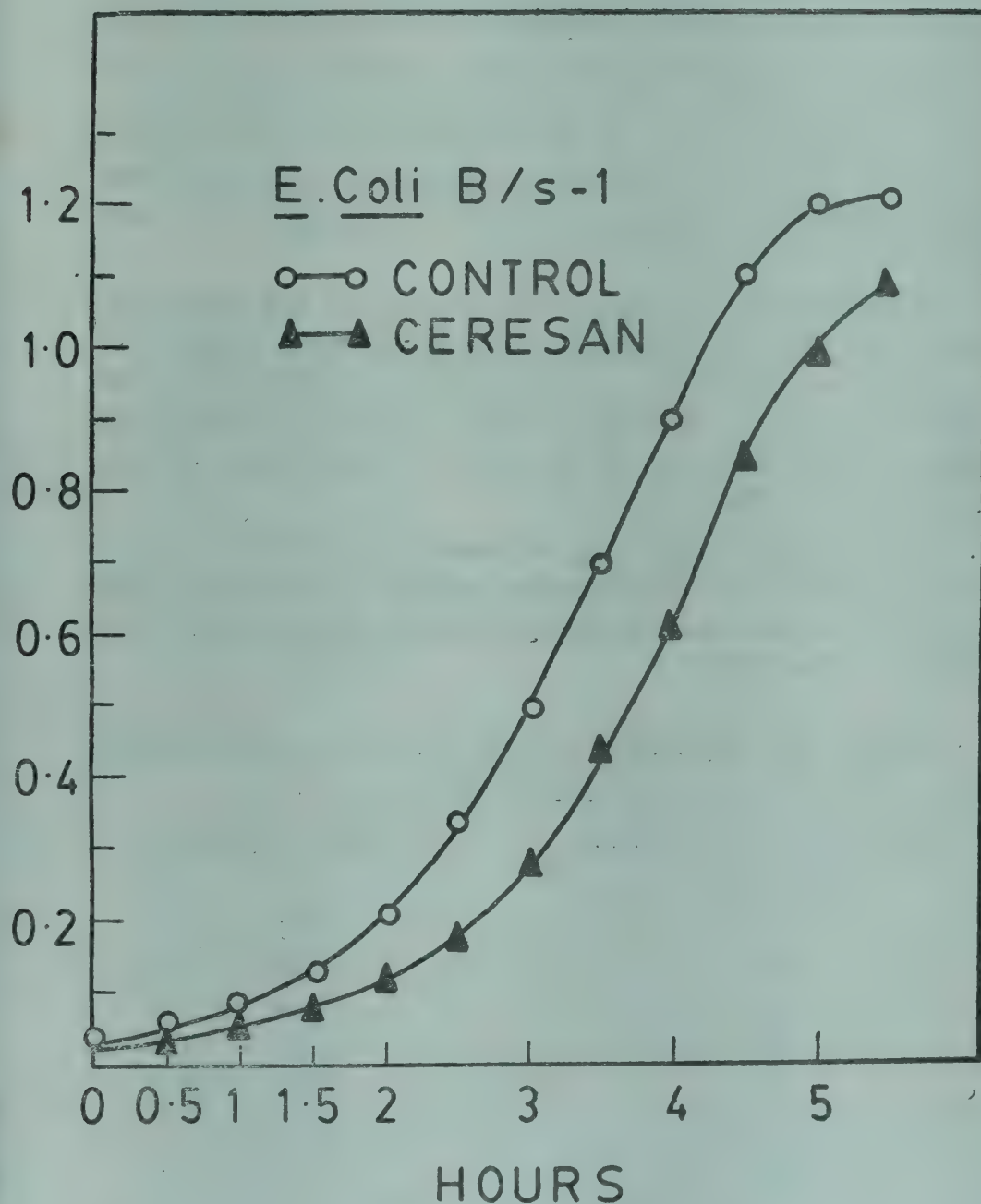


Fig. 14. Exponential growth curve of a population of bacterial cells. The lower curve shows lesser growth due to treatment with a pesticide ceresan. Optical density is proportional to the number of cells present.

CARRYING CAPACITY : To understand how population of most organisms exist in a state of balance with the resources of the environment the term carrying capacity is used. This means the ability of the environment to support a population mainly in terms of the availability of energy and nutrients. It has to be understood in terms of a particular population and must include everything that affects the size of that population.

If a population is growing exponentially it will under normal circumstances, quickly reach the carrying capacity of the environment. As the carrying capacity is approached the rate of population growth will slow down and eventually the death rate will be equal to the rate of recruitment of new individuals into the population.

Another way of expressing exponential growth of a population is to calculate the percentage increase in a period of time and for man an annual percentage increase is taken into consideration (Table III).

TABLE III. *Different rates of increase in doubling times of population*

Rate of increase expressed as %/year	Doubling time in years
0.1	700
0.5	140
1.0	70
2.0	35
3.0	24
7.0	10
10.0	7

If the population is increasing at only 0.1 per cent a year the population will double in seven hundred years, but if the rate is 7% per year then the population will double in only ten years.

Studies by many demographers have shown that, allowing for some fluctuations occasional downturns the size of the population on the earth as a whole has, over long periods, steadily been growing.

TABLE IV. *Population growth over long periods*

	Period	Growth (in millions)		Years required to double the population
		From	To	
BC	7000-4500	10	20	2500
	4500-2500	20	40	2000
	2500-1000	40	80	1500
	1000- 0	80	160	1000
AD	0- 900	160	320	900
	900-1700	320	600	800
	1700-1850	600	1200	150
	1850-1950	1200	2500	100
	1950-1990	2500	5000	50

(estimated)

It has been estimated that the population of the earth in the year 2000 will be between 4.9 and 6.9 billion. Most probable figure is 6.3 billion. The annual growth of the population will be around 60-70 million. The population growth rate in India is between 2.3-2.5 per cent per year. One of the reasons for the increase is a steady decline—all over the world—in the mortality rate which is again due to the improved standards of living.

Should the population growth continue the resources of our planet (like the amount of sugar for example, in the case of yeast or bacterial cells) will sooner or later run out. Of course, there are factors like epidemics, famine and war which can impede the growth. The other factor is the conscious control of population growth through self imposed family planning.

DYNAMICS : Individuals within a population enter into varied interactions with each other besides interacting with the adjacent populations. These interactions are termed positive or negative depending on whether they produce harmful or beneficial effects on the interacting individuals or populations. The stability of an ecosystem depends on the sum total effect of these two types of interactions.

Positive interactions are those where individuals live adjusting with each other such as symbiosis where both individuals derive benefit out of each others presence.

Negative interactions are competition, predation, parasitism, etc.

PREDATOR-PREY INTERACTIONS : Interactions between predator and prey are different from parasite-host relations in that the predator and prey maintain a more dynamic equilibrium. At high rate of parasitisation the parasites cause the death and resultant elimination of the hosts. But a predator never eliminates the prey completely. When the predator feeds on only one species of prey it is termed an *obligate predator*. When it feeds on more than one species it is known as a *facultative predator*. Lotka (1925) and Volterra (1931) were the first to study, separately, the way in which population growth was influenced by predation. They showed that an increase in the predator population was followed by a decrease in the prey population, and, at a certain level the process was reversed. Or, in other words, both the predator and prey populations fluctuated with time forming population cycles, the number of individuals rising and falling at regular intervals. Some workers proposed a model suggesting that violent oscillations will occur in a single prey and single predator populations if their external conditions are kept constant. Further studies revealed that the prey-predator interactions never cause a total extermination of either the predator or the prey. Two variables namely predator and prey densities affect predation. It was noticed in one inter-

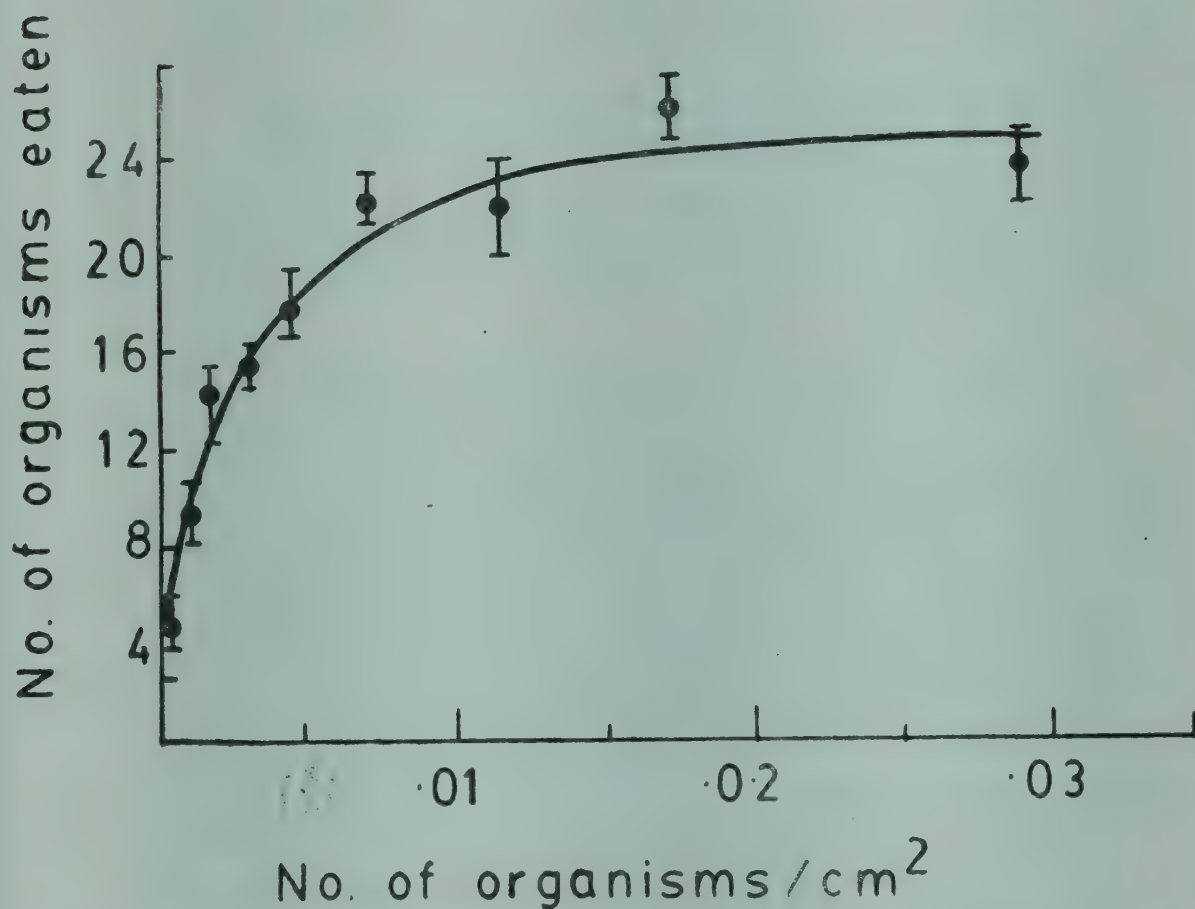


Fig. 15. Functional responses of individual organisms to density of adult female organisms.

action that as the prey population increased in density, predators also increased in density, consuming more and more of prey. This is termed as functional response (Fig. 15).

3 Energy and the Ecosystem

Modern ecology relies on a variety of disciplines like physics, chemistry, mathematics, meteorology, climatology, geology, geography etc. An essential aspect of these studies is concerned with energy transformations occurring within ecosystems. The quantity of incident energy from the sun per unit area of the ecosystem and the efficiency of conversion of this energy by other organisms is a basic principle. For the effective functioning of ecological systems energy transferring mechanisms from organism to organisms as observed in food chains, are of prime importance. Ecological energetics deal with this aspect of ecological studies. The autotrophs (plants) and the heterotrophs (animals) utilise this energy. Such interconversions of energy closely follow the laws of thermodynamics and it may be said that the solar energy entering the ecosystem is equivalent to the heat energy leaving the system.

For any form of work energy is necessary—for growth, movement, reproduction, breathing etc.—and all kinds of organisms such as microbes, plants and animals require energy. The kinetic and potential energies change and are expressed as heat, light, mechanical, chemical and several other forms. For the use of organisms the chemical form of energy is the most suitable as it is easily available, can be stored and converted for immediate use with the body. The chief source of energy is the sun and at the outer atmosphere of earth an average rate of energy transfer is about $2880 \text{ kcal/cm}^2/\text{day}$.

Man utilises this energy through natural food chains. Through the interaction of the incoming solar radiation with

green pigments—chlorophyll—of the leaves of vegetation that large amounts of this energy is converted to chemical energy which is useful in the production of organic matter.

The other utilization of energy is for technological fulfilment—where both solar energy and fossil fuels such as petroleum are used. Of course, nuclear energy utilisation is also coming up in a big way in the developing countries as well.

Solar Energy

It is estimated that energy radiates from the sun at the 'astronomical' rate of some 10^{23} kW. Thermonuclear fusion reactions at the sun's central core temperature of something just below 2×10^7 °C result in the collision and coalescing of hydrogen ions, such that four protons combine to form a helium nucleus with a frequency so great that 3.6×10^{26} J of energy are released per second. Translated into units of mass this is equivalent to 6×10^8 t of helium being so formed every second, according to simplified equation :



The temperature of the sun's surface is between 5500°C and 6000°C and, at this temperature, the greatest intensity of emitted light falls in the visible spectrum at around 600 nm, coinciding with the orange zone. About 98 per cent of the total emitted energy from the photosphere is conveyed by radiation of wavelengths between 250 and 3000 nm, with as much as 50 per cent from 350 to 750 nm.

The energy of each quantum of radiation is that expressing the minimum value which can change in the confines of a system exhibiting wave-like characteristics, and the quantum itself is directly proportional to the frequency of its associated radiation. The energy of a single quantum of light radiation is termed a photon, and is equal to about 3×10^{-19} J. It is the product of the frequency of light ν and

the very small value of Planck's constant ($6.6 \times 10^{-34} \text{Js}$), expressed in the relationship $E=h\nu$, where E is the energy of a single quantum. The total power intercepted by the earth is $1.8 \times 10^{14} \text{ kW}$, equivalent to $5.6 \times 10^{24} \text{ J}$ of energy per annum; and $3 \times 10^{24} \text{ J}$ of this value, i.e., about 50 per cent actually arrives at the earth's surface each year, having travelled through the height of the atmosphere. This last figure is equivalent to approximately 75 times the present total proven world fossil fuel reserves but must be set beside its diffuse and variable nature, with a peak solar energy flux of around 1 kW/m^2 only.

Absorption is a far more selective phenomenon with respect to the wavelength of the incoming radiation. Virtually all the radiation in the ultra-violet range is absorbed by the ozone layer in the uppermost reaches of the atmosphere where dissociation and recombination of O_3 , O_2 and O occur to form a steady state condition. Further substantial reductions in this potentially biologically harmful zone of the spectrum below 350 nm wavelength are brought about by absorption due to N_2 and N , while molecules of water vapour and carbon dioxide absorb most strongly in the near and middle infra-red respectively. Thus absorption accounts for the loss of a further 20 per cent of the original solar constant although the visible region is relatively clear of absorption bands. The overall radiation regimes in different parts of the world may show a great degree of variability but the actual total of annual insolation is much less diverse. North-western Europe is not considered to be particularly well endowed with solar energy, but from Table V, it may be deduced that the UK, for instance, receives as much as 40 percent of the insolation of the Middle East as exemplified by Israel. It is with regard to the relative seasonal variations that countries such as Australia, Israel and Japan are better placed than northern European countries. In addition to receiving comparatively little solar radiation in winter, when it is most needed for the space heating of buildings

etc., the duration of the UK growing season for plants is also severely curtailed, with a consequent reduction in the annual crop productivities attainable in latitudes near the tropics.

TABLE V. *Insolation in selected countries on horizontal surfaces [27] Insolation (MJ/m² day).*

Location	Latitude	Mid-summer	Mid-winter	Annual mean	Midsummer/midwinter ratio
England & Wales	53°N	18	1.7	8.9	10.6
Central USA	36°N	26	11	19	2.4
Southern France	44°N	24	5	15	4.8
Israel	33°N	31	11	22	2.8
Australia	30°S	23	13	20	1.8
Japan	40°N	17	7	13	2.4
India	18°N	26*	14*	20	1.9

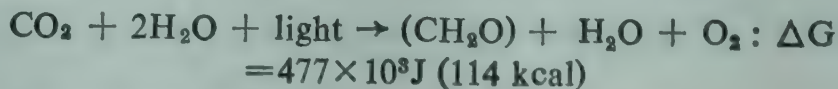
*In many part of India the maximum and minimum insoloations occur in April and June respectively.

The mechanisms of photosynthesis

Photosynthesis is the key mechanism to which all past fossil fuel production and present food and fibre (and some energy) production owe their origins. It is the process by which a small percentage of the quanta originating from the sun, is collected within green plants algae and some bacteria and converted to reduced carbon and stored energy. The problem of effective solar energy storage is still a difficult one for man to solve employing artificial devices, but plants have been doing it naturally for billions of years. It is an important concept, for the usefulness of energy capture per se, is

severely limited without an accompanying means of fairly long term storage, so that it may be 'tapped' as and when required.

The overall photosynthetic process occurs within the chloroplasts of green plants and the several biochemical reactions involved may be reduced to the following simplified equation :



The light energy is absorbed by the chlorophyll and carotenoid pigments of the chloroplasts and this results in a separation of charges (Fig. 3).

Energy Resource and Power

The future of any country and for that matter the whole world depends on availability of energy and power.

Some conventional and uncoventional sources of power are :

HYDRO (ELECTRIC) POWER : Here the raw material is water which is not consumed in the process of production so that the same water can be used for irrigation. No transportation or pollution (as is the case of coal) is involved. As the power plants are based on reservoirs so care has to be taken about the ecological balance and enviroment. Also vagaries of weather affect the plant (less rainfall etc). The first small hydro power station in India was commissioned in 1897 at Darjeeling.

THERMAL POWER : In the conventional power station coal is used for firing the boiler to produce steam. The super thermal plants require sophisticated technology and maintenance. Air and water pollution in and around the area is a major environmental hazard. As fossil fuels such as coal and petroleum are depleting fast, alternative source of energy will be necessary. Badarpur (Delhi) and Farakka (West Bengal) are two of India's several thermal power stations.

NUCLEAR POWER : In this case nuclear fission (Chapter 4) produces the heat to make steam. Although the power potential is high but so is the pollution potential and the capital cost. Keeping in view its controlled application for peaceful uses our country is fast developing this source.

SOLAR POWER : The Sun's energy can be used to produce electricity by heating water to turn into steam, which through turbiness rotates the generator. The other method involves directly converting solar energy to electricity through solar heaters of 'chulas'. The methods are developing.

4 Pollution

Human beings have become numerous enough to overcrowd the earth itself. Our industries, agriculture, mining and cities have expanded until their outputs and wastes are polluting the long-unpolluted air, water and land, and are rapidly depleting the nonrenewable earth resources on which all depend. More disturbing is the fact that the combined effect of overcrowding, pollution and depletion are threatening the natural cycles and the huge diversity of natural things that sustain all that exists on the earth, under it, or closely above it. The deterioration of the quality of our environment about which we have become aware in recent times is not a sudden development although it seems as if we have realised the matter suddenly during the past few years. The fruits of technological progress allowed us to overlook its more harmful consequences on the environment or the ecosystem.

The transformation of the environment in the course of production by society is inevitable. Not only human society but in fact any form of life affects nature with its activity.

Radiation pollution

NUCLEAR ENERGY AND RADIATION HAZARDS : In 1973 the organisation of Petroleum Exporting Countries (OPEC), unilaterally raised the price of its commodity—oil, by 300 per cent and sent a shock wave running through the world's industrialised communities. Quite suddenly and understandably attention was focussed towards the sun as an alternative to fossil and fissile fuels. Also, it has been

estimated that the reserves of fossil fuels like coal, oil and natural gas are very limited and will not be lasting more than a few hundred years (if consumed at the present rate). There are other various environmental problems associated with the burning of fossil fuels (pollution, mining etc.). For these reasons alternative energy sources are necessary. India's endeavours in this field are evidenced through Kalpakkam and other nuclear power plants such as Rajasthan Atomic Power Station (RAPS), the Madras Atomic Power Station (MAPS) and Narora Atomic Power Project (NAPP).

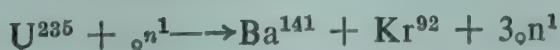
NUCLEAR POWER : We all know that energy can be released from nuclear reactions either by fissioning (splitting) an appropriate heavy nucleus or by combining appropriate light nuclei (fusion).

Einstein's equation relating energy E to mass m is : $E=mc^2$, where, c is the speed of light. If E is expressed in ergs and m in g and ' c ' in cm/sec, then for 1 g of matter the energy is $E=1 \times (3 \times 10^{10})^2$ ergs = 900 billion ergs or 2500 million kilowatt hours.

Similary one pound of matter will give energy equivalent of 10 million tons of TNT.

Both fission and fusion involve the rearrangement of nucleons (the collective term for neutrons and protons) into different nuclei so that energy is released due to mass defect.

FISSION : If U^{235} is bombarded with slow neutrons then the chain reaction which takes place can be seen in Fig. 16. This chain reaction is very important and the names associated with this are : Enrico Fermi, Lise Meitner, Otto Hahn, Hans Bethe etc. The reaction is :



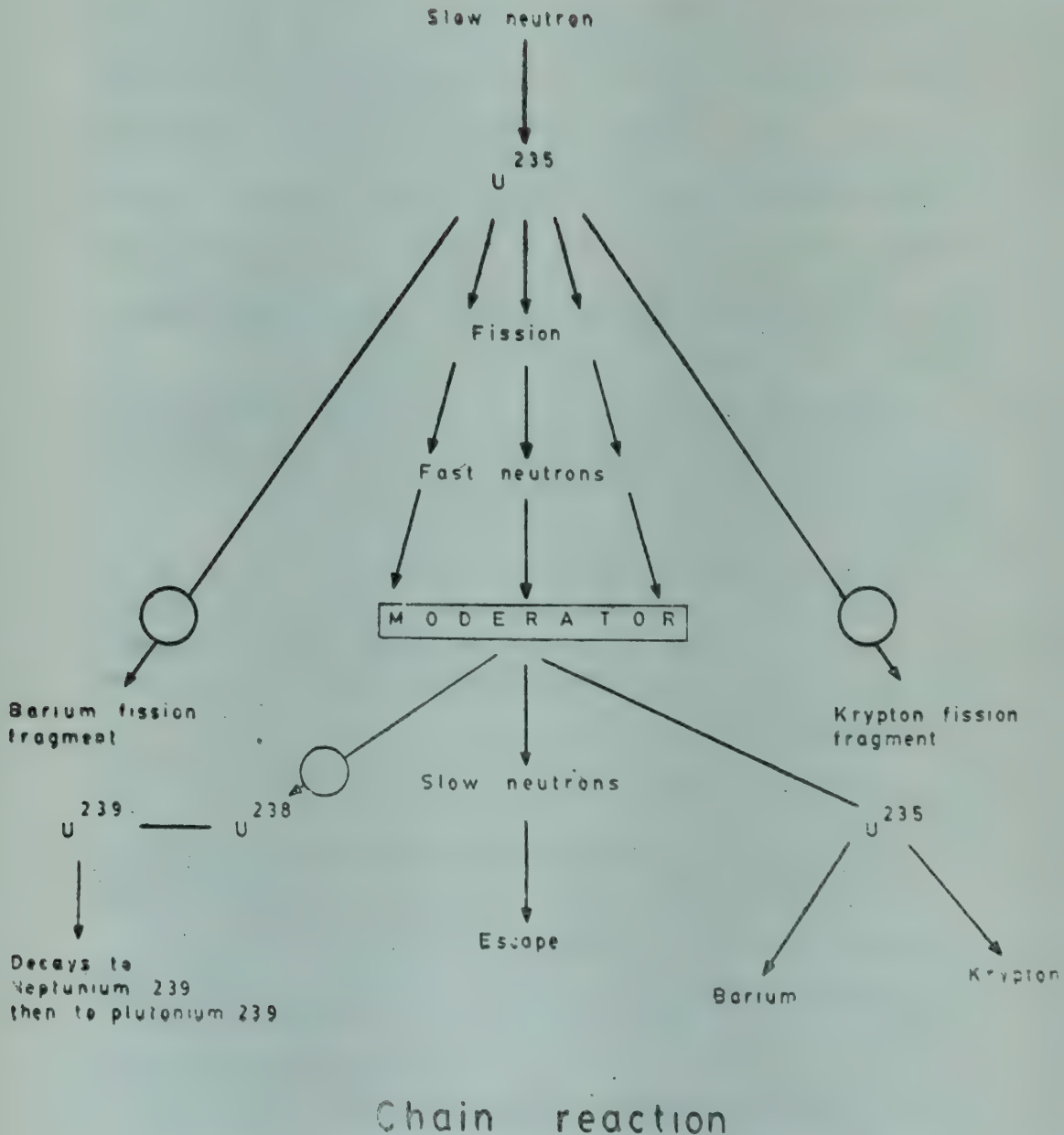


Fig. 16. Chain reaction in a nuclear reactor.

In nature U^{238} is more abundant than U^{235} . It does not fission with slow neutrons, but captures them, making it difficult to maintain a chain reaction. U^{235} is only 0.7 per cent.

It was found that some disappeared in the break up as part of the uranium atom was converted into energy. As the chain reaction proceeds theoretically we get more and more number of neutrons. In reality as many neutrons fail to split another atom, with time this chain reaction weakens. This happens because most of these neutrons are fast neutrons. Therefore, to overcome this difficulty moderators like graphite, or heavy water were used. It was known to scientists like Fermi (1942, Uranium graphite pile) that graphite (pure carbon) did not absorb neutrons but simply bounced off these nuclei like a rubber ball against a hard surface thereby decreasing the velocity. Also there were substances like cadmium which absorbed (like sponge) the passing neutrons. A combination of the impervious and the absorbing nuclei gave Fermi the tool he needed to control nuclear breakup. He embedded the uranium (nuclear) fuel for the reaction in a huge mass of graphite so that after bouncing the neutrons will be slowed (thermalised) to more efficient projectiles for hitting the uranium nuclei and breaking them in two. Now, by inserting cadmium rods the faster or runaway neutrons are absorbed totally. The rods are arranged so that they could be pushed into or pulled out of the pile, depending on whether the reaction needed to be slowed or speeded.

Power of nuclear reactor

If 'A' is the number of nuclei undergoing fission,
then, $A = nv N \sigma V$(1)

where n = average neutron density, i.e., neutrons/cc

v = average speed, so that nv is the average
neutron flux

N = no. of fissionable (U^{235}) nuclei/cc

σ = cross section for fission

V = volume of the reactor. It is seen that 3.1×10^{10}
fissions/sec produce 1 watt of power (P)

$$P = \frac{nvN \sigma V}{3.1 \times 10^{10}} \text{ watts}$$

The reactor requires cooling helium gas or air cooling is used.

FUSION : Solar energy is the only proven very long term major energy source. The vast output of energy by the stars (including our sun) was thought to originate from some kind of nuclear transformations. Professor Hans Bethe theoretically explained this phenomenon as follows : the extremely high temperatures found in the sun and the enormous pressure exerted by its great bulk cause protons to join together in the process called fusion. In the fusion reaction four protons are combined to form the nucleus of a helium atom. The mass of this nucleus is very slightly less than that of the four protons. The missing mass has been converted into the energy of the sun.

Controlled fusion has not yet been demonstrated in the laboratory, but researchers are approaching the necessary conditions. This has the promise of being another energy source of long duration.

RADIATION HAZARDS : For whatsoever purpose nuclear energy is used—be it for peaceful uses, or nuclear warfare—the physical and bio-environment cannot get away with its hazards. There are the delayed effects of fall out and the increasingly important hazards of the peacetime uses of radiation. Power reactor accidents may occur (which in other countries already have); the radioactive by-products and spent fuels of reactors will need to be contained and safely disposed of; radiation and radioisotopes will be finding wider use in technology as well as in scientific and industrial research. The medical profession must continue its evaluation of the risks attending diagnostic and therapeutic irradiation of patients and its efforts to reduce these risks to the essential minimum. Biological effects depend on radiation *absorbed*; the unit is a *rad*, and $1 \text{ rad} = 100 \text{ ergs g}^{-1}$ of energy absorbed.

The present Systemme Internationale Unit of absorbed dose is the *gray* (Gy) = 100 rad ,

The present unit of radioactivity is the Curie (Ci), which is based on the radiation given off by 1 gm of radium. It is 3.7×10^{10} disintegrations per second. Again the latest unit is the becquerel (Bq), which is equivalent to 1 disintegration per second.

DIFFERENT TYPES OF RADIATIONS : The following are the different types of radiation one encounters when handling radioactive sources, working at nuclear power plants with accelerators, or from nuclear fallouts. Alpha (α) rays arise from the disintegration of unstable isotopes of elements having atomic weights > 150 . They have a short range (approximately 5 cm) in air, lose energy rapidly by collisions and are highly biologically effective. Beta (β) rays are electrons (or positrons). In air the energetic particles may have a range of about 3 m. Gamma (γ) rays are not particles, but quanta of electromagnetic radiation with much more energy than visible light. X-rays in many ways are similar to gamma rays. They have very long range in air, 4m or more.

Neutrons (n) are particles with unit mass and no charge. They only react by direct collision with other elements, and have a very long range in air.

Neutrons and gamma rays will pass through several centimetres of lead but α (alpha) and β (beta) rays can be stopped by quite thin sheets of light materials, such as aluminium or perspex.

HALF LIFE : Each radioactive isotope (nuclide) has a characteristic instability, which is not altered by physical treatment or by formation of chemical bonds. It is impossible to predict when an individual atom will decay, but one can say that, of a finite assemblage of atoms, half will have decayed by the end of a *time interval* characteristic of that nuclei (Fig. 17). This time interval is the *half life*. At the end of a second half life half of the unstable atoms remaining

will have decayed, and so on. Half lives vary from seconds to billions of years (Table VI).

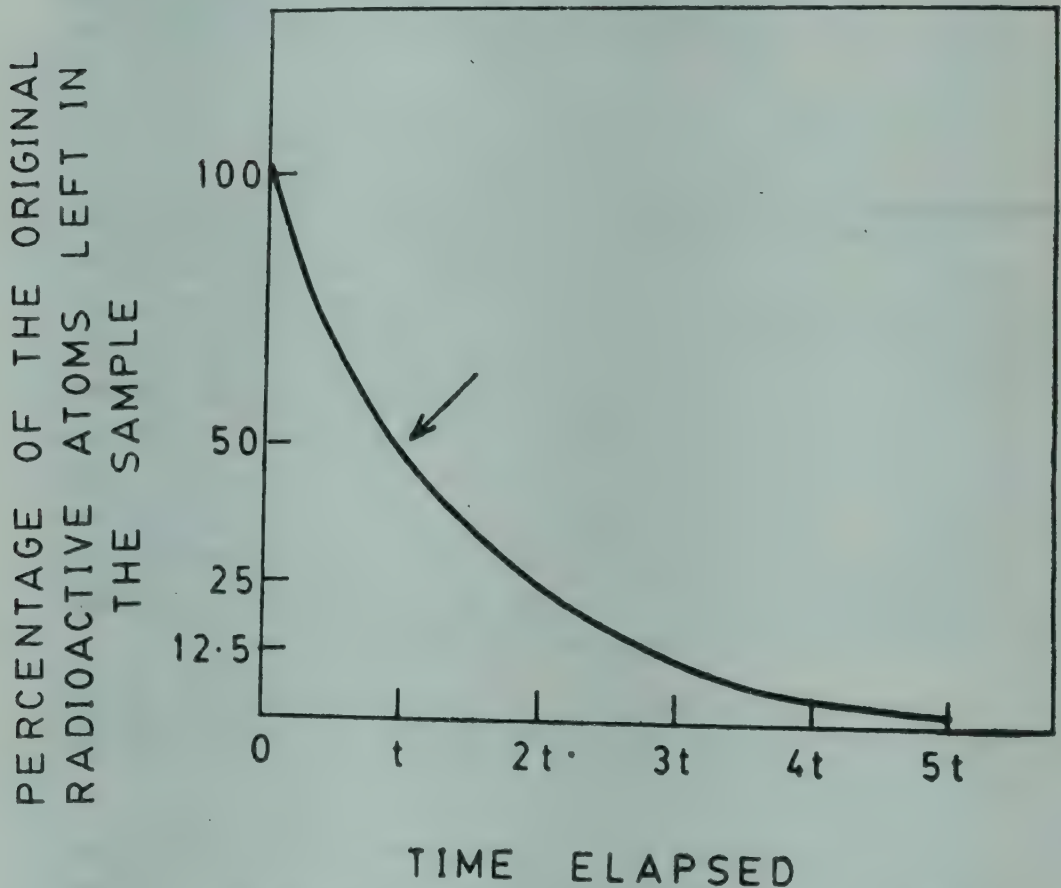


Fig. 17. The half-life of a radioactive isotope. The arrow indicates a single half-life.

BIOLOGICAL DAMAGE CAUSED BY RADIATION AND HAZARDS OF NUCLEAR ENERGY PRODUCTION : α , β and γ rays cause damage by raising atoms, which they approach or collide with, to a higher energy level ; most of the time an orbital electron is lost altogether (ionisation). The molecule to which the excited atom is bound becomes temporarily much more reactive. Most damage is caused if a chain reaction is set up.

Because of their very limited range α and β rays are really only effective if they are inside the body, whereas γ rays and

neutrons are very dangerous outside the body. Eyes must be protected from these because they lead to cataract formation.

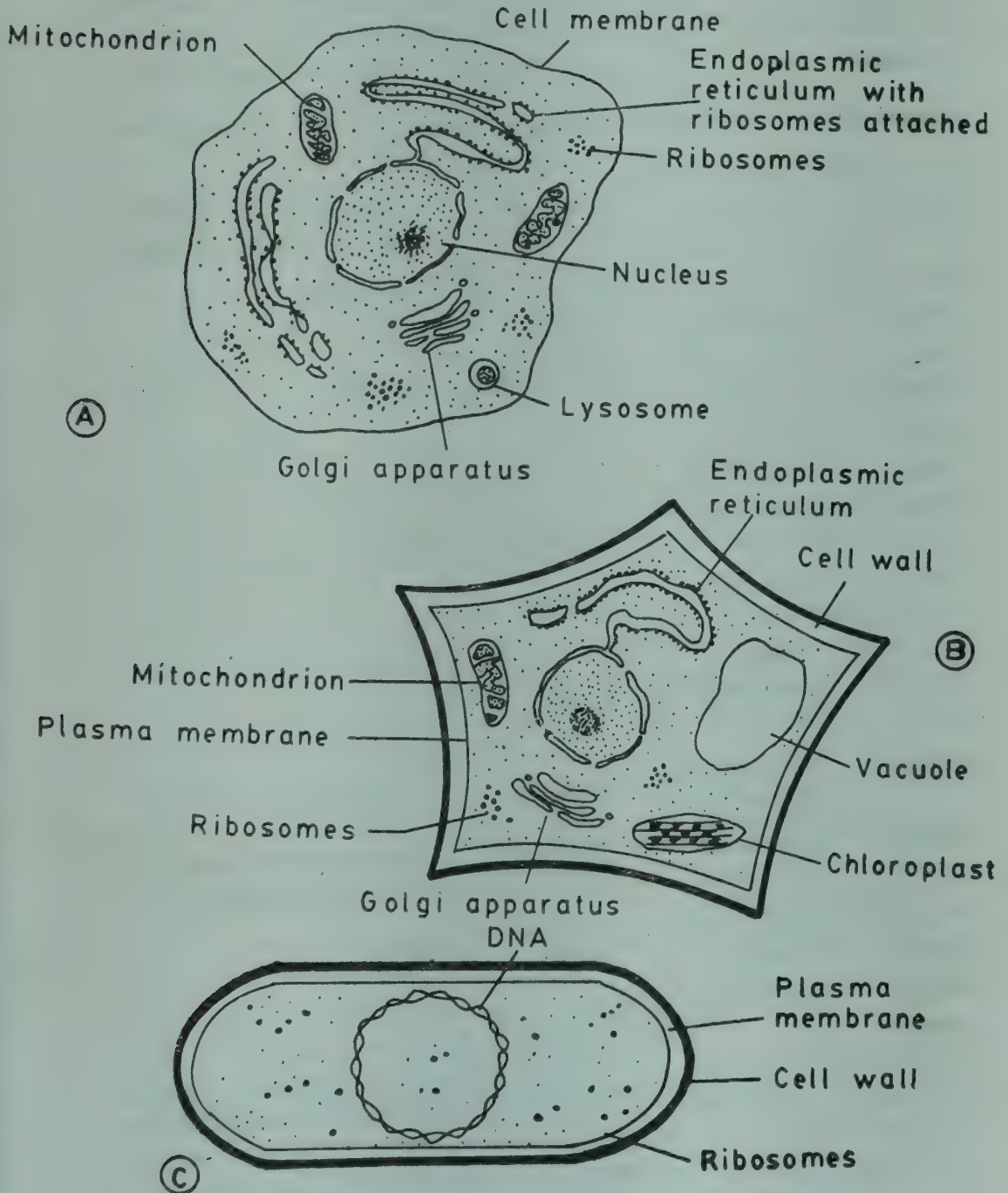


Fig. 18. Generalised cell. A : animal B : plant C : bacterium,

Neutrons mostly disrupt molecules-including water-to give a recoil proton (H^+) and a reactive negatively charged ion and they can also transmute elements. It is in general the nucleus of cells (Fig. 18 A, B, C) that is most sensitive to radiation damage. X-and γ -rays are used for cancer therapy, or for

TABLE VI. *Radioactive nuclides likely to be produced by fission.*

Nuclide	Major radiation	Half-life	Element with similar biochemical properties
^3H	β (very weak)	12.3yr	hydrogen
^{85}Kr	β (medium)	10.6yr	none
^{89}Sr	β (strong)	50.4 day	calcium
^{90}Sr	β (medium)	28 yr	
^{91}Y	β (strong)	58 day	none
^{99}Tc	β (strong)	2.1×10^5 yr	none
^{103}Ru	β (weak) γ (weak)	40 day	none
^{129}I	β (weak) γ (very weak)	16×10^6 yr	iodine
^{131}I	β (medium) γ (weak)	8 day	
^{137}Cs	β (medium) γ (medium)	30 yr	potassium
^{140}Ba	β (strong)	12.8 day	calcium (but not readily absorbed)
^{141}Ce	β (medium)	32.5 day	none
^{144}Ce	β (medium)	284 day	
^{147}Pm	β (medium)	2.6 yr	none
$^{237}Np^*$	α	2.2×10^6 yr	none

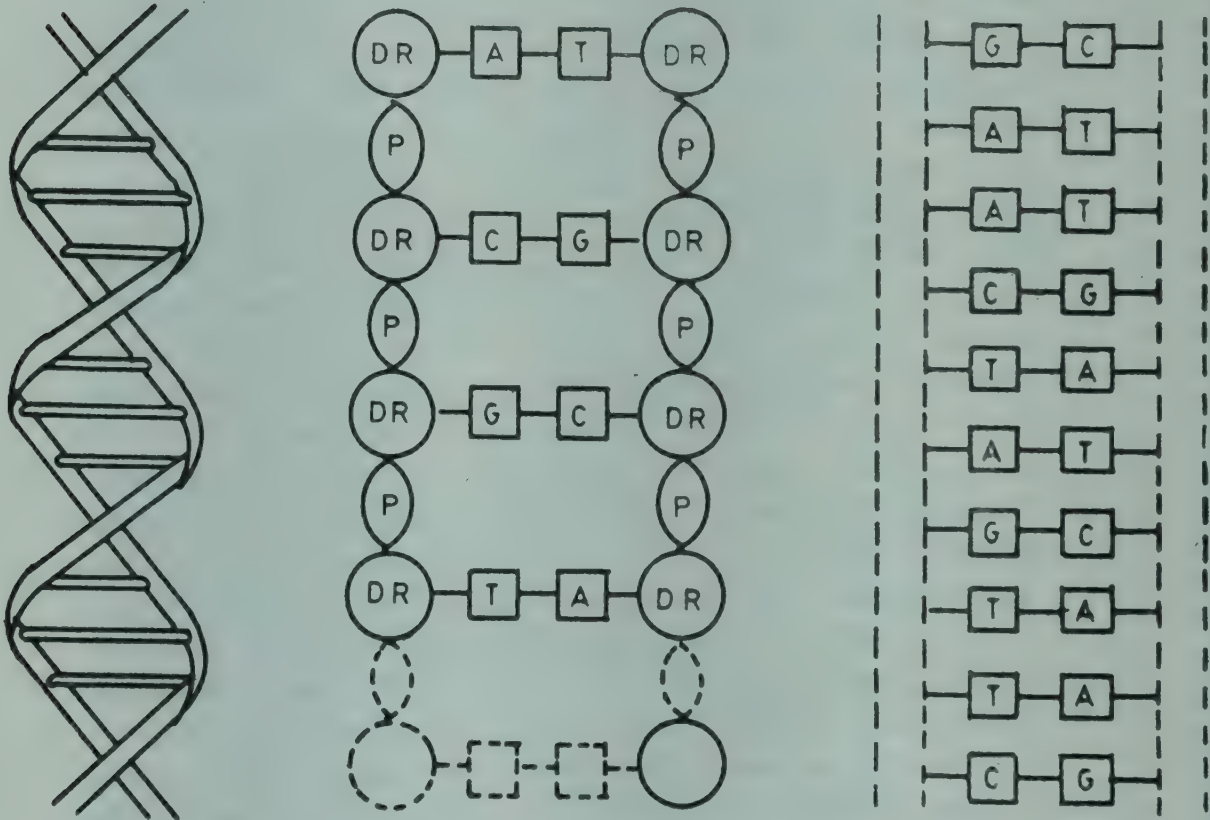
*Not a fission product ; it arises from neutron capture by ^{235}U and ^{238}U . Traces of neptunium, like other heavy metal ions from yttrium on, may be absorbed into bone, although they are not really biological analogues of calcium.

sterilizing male insects is one method of biological pest control. Thus the tissues most at risk are those where there is a high concentration of nuclei with frequent cell division for example, bone marrow.

Radionuclides absorbed into bone are particularly dangerous because they tend to stay there a long time, whereas atoms in other sensitive sites such as liver or intestinal epithelium are much more readily metabolized.

The DNA of the nucleus is very readily damaged by radiation which causes ionization. In theory, it only needs one chemical change in a single purine or pyrimidine base of a stretch of DNA (Fig. 19) for a point mutation to occur, because there will be a misreading on the next occasion when that length of DNA is transcribed. In practice, however, cells contain rather efficient repair mechanisms for replacing damaged stretches of DNA. Early recognition of the long term ill effects of low dose-radiation and consequent widespread concern led to the formulation of various types of measures during the past few decades which have been responsible in keeping radiation exposure to workers in nuclear power plants and industry as well as general population to as low a level as can be reasonably achieved. The present day radiation health protection measures have been the outcome of the systematic documentation and careful analysis of radiobiological research information including epidemiological surveillance that has been accumulated for several years. Probably due to the absence of definitive information on the long term ill effects of environmental chemical pollutants, similar effort were not made to assess the potential health hazards that may be associated with conventional fossil fuel based energy and other industrial operations. In recent years however there is growing concern that most of the hazardous biological effects induced by chemical pollutants are similar to those by atomic radiation. The community of scientists concerned with public health is now feeling the desirability of an integrated approach for tackling the problem of risk assess-

ment on the same philosophy and pattern by which radiation risk assessment is done and radiation protection measures organised.



A = Adenine; T = Thymine; G = Guanine; C = Cytosine;
DR = De - oxyribose sugar; P = Phosphate

DNA DOUBLE HELIX

Fig. 19. DNA (deoxyribonucleic acid) double helix with the different bases and sugar (deoxyribose)—phosphate chain.

Scientists like Stern Glass suggested that the release of 20,000 megatons anywhere in the world could result in elimi-

nating any surviving infants. He drew this conclusion from the effect of the first series of atomic tests carried out in the USA. More than 1600 to 2400 kilometers away from the test site the mortality rates of between 3-4.5 per hundred live births increased by 20-30 per cent.

During early 1950s it was discovered that radioactive strontium became concentrated in cow's milk and was transmitted along with calcium to the bones of the developing human foetus and body.

Observations on pregnant women who had been exposed to X-rays indicated the possibility that ova and embryos could be from 20-50 times more sensitive to the possible development of leukaemia than the mature adult.

The genetic hazards may be summarised as follows :

Radiation induced mutations, like other mutations however induced, are mostly deleterious. Under a given set of conditions mutation appears to be induced in linear proportion to exposure thus there is no threshold below which radiation will produce no mutation.

The great outcry raised by scientists and the public all over the world has to a certain extent caused the cessation of nuclear tests in the atmosphere, due to which environmental contamination has markedly abated. But this is far from achieving the objective of banning nuclear proliferation other than for peaceful uses.

Air Pollution

Almost all chemicals released into air eventually find their way into soil, often being washed down by rain. Chemicals such as pesticides are often sprayed as mists which may drift for several kilometres from their intended point of application. There are gaseous pollutants also, which are deliberately or accidentally released into air. Many of these have harmful effect on the lungs. Biochemical informations are sometimes

lacking about many of the very dangerous aerial pollutants such as asbestos fibres, which can cause virulent lung cancer (mesothelioma), which can occur many years after the actual exposure. Similar lack of knowledge applies to the nitrogen oxides from car exhausts which form the irritant component of automobile smog and in a more limited environment, to nickel and chromium containing dusts, which can initiate lung cancers. Turbulence in the atmosphere distributes fall out from volcanic and nuclear explosions all over the Earth's surface. Even circumpolar snows contain traces of radio strontium and general pollutants such as lead and chlorinated hydrocarbons.

Houses and factories need energy and this is provided by burning oil and coal in power plants. Urban pollution has

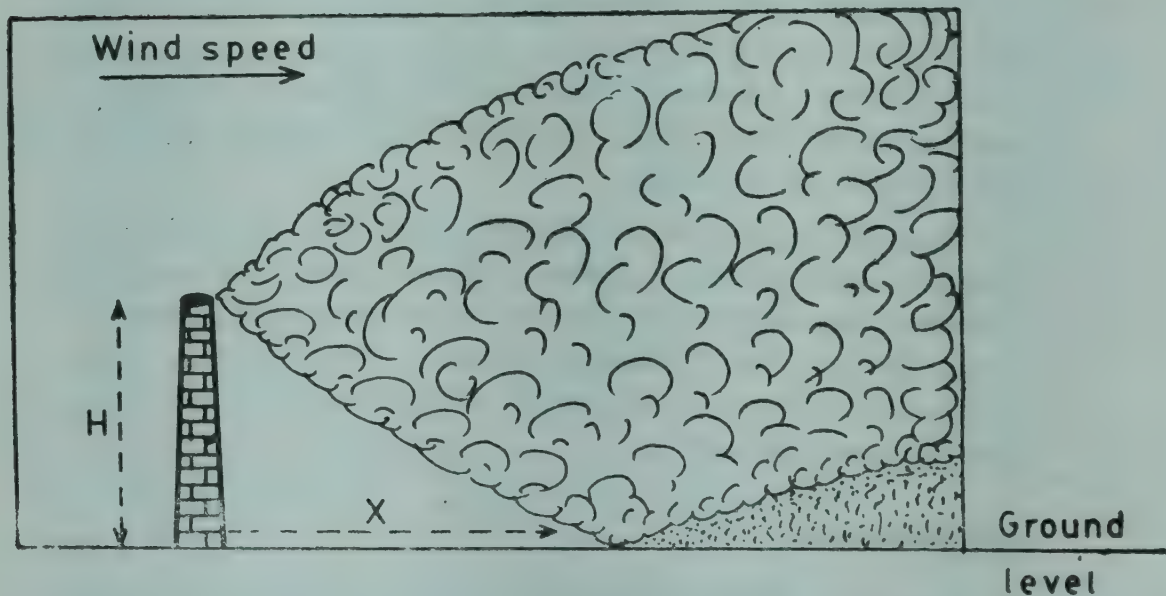


Fig. 20. Smoke release from a factory chimney, The horizontal distance X before the smoke reaches the ground depends on the wind-speed, on the square of the height of the smokestack (H) and on the temperature of the flue gases. Downwind from X the concentration of smoke will be more intense—as shown by the spotted area—because of reflection from the ground surface.

been avoided partly by cleaning the smoke and partly by emitting into the upper atmosphere. By building the chimney of the required height (Fig. 20) much of the gases enters the upper atmosphere where there is perpetual turbulence, so that they are swept away and diluted. As gases CO, SO₂ and SO₃, fluoride are the common air pollutants. Also heavy metals—or smelter effluents and car (automobile) exhaust. But these are more important as soil pollutants (to name some cadmium oxide smoke—often an impurity in zinc smelting and Pb.). The example of the Taj Mahal is one aspect of the present research pertaining to air pollution.

Water pollution

Pollution of fresh water is one of the most serious environmental problems for the world as a whole. Unless circulation from the deep ocean is inadequate, heavy marine pollution does not extend more than a few miles offshore. The situation is very different for fresh water, and it is difficult to see how many of the problems can, with present technology, be alleviated. The further a body of water (running or still) lies within a highly-polluted area, the higher the concentration of nutrients that it will contain. It is necessarily more active biologically.

Industrial processes require vast quantities of water, often for cooling, but sometimes to dilute waste products to an acceptable concentration before returning them to rivers. The very large volumes sometimes quoted for industry's requirements must be assessed with caution—the water does not simply disappear, as ultimately most of it returns to source, and the water need not be drinkable. Nevertheless, effluent water from industrial plants is always more impure. The temperature differential is often the most important factor. Power stations, particularly nuclear plants, are especially bad sources of heat pollution.

A serious source of industrial pollution is the leaching of sulphides (particularly pyrite, FeS₂) from mine workings or

dumps. Dissolved O_2 converts this to $FeSO_4$ and then to ferrous sulphate, which is hydrolysed. Ferric hydroxide $Fe(OH)_3$ is precipitated in the stream bed, and dilute H_2SO_4 flows off. The consequent high acidity and the loss of O_2 makes the water biologically sterile, so it is both useless as a diluent, and unfit to drink. In heavily polluted waters downstream the sulphate may be reduced by anaerobic bacteria to sulphide which is both toxic and unpleasant. Salts, especially potassium chloride from salt mines, may also cause problems.

Up to a point, river may be re-used. On each occasion the water that is returned, although technically unobjectionable adds a quota of nutrients, particularly nitrate, so this re-use cannot go on indefinitely without dilution by fresh clean water.

Dilution of polluted effluent by purer water is a simple thing to specify, but the purity characteristics of the diluent water need to be discussed in some detail. Water flowing from the drains or sewage works of a town can almost always become biologically and biochemically more pure, if time is allowed for microbial action to go to completion. This requires a large volume of water so that the concentration of pollutants remains low, a relatively neutral pH. absence of obvious biochemical poisons such as cyanide, phenols, or copper salts and abundance of dissolved O_2 . In practice, the minimal diluent flow is five times of flow of effluent, if regeneration within a reasonable distance downstream is to be achieved.

Of all these requirements, the need for O_2 is the greatest. Since the solubility of gases decreases with rising temperature while the rate of biochemical activity often doubles for every $10^\circ C$ rise in temperature, one may see why the temperature of water entering rivers from industrial plant is so important. Thus a large volume of effluent, even pure distilled water, coming from a power station at, say, $40^\circ C$, could be disastrous. The effect of increased temperature on river life was shown

in England in 1976, when prolonged drought and intense sunlight raised the temperature of many rivers to 25°C, resulting in the death of most fish. Along the S.E. coastline of the U.S.A., the summer heat and thermal pollution from industry regularly raise the temperature of rivers to 33-35°C. All living things die except a few thermophilic bacteria, which are useless for regeneration purposes. Why is the oxygen so vital? To see this, we must consider how human effluent is dealt with in Western countries. A well-nourished adult excretes about 8 g of combined nitrogen per day. Of this about 6 g is in urea, $\text{NH}_2\text{CO.NH}_2$, 1 g in uric acid and 1 g, mostly as bacterial protein, in faeces. The latter two can fairly be broken down to derivatives that may be re-assimilated by growing bacteria. Urea is quickly hydrolysed by the enzyme urease to CO_2 and ammonia, which is toxic to most higher animals, probably because it reduces the activity of the Citric Acid Cycle in the brain. The limit of toxicity for ammonia is low and often surprisingly sharp. Trout, for instance, will die after 24 h in water containing 2 parts per million of NH_4^+ but will survive at a concentration of 1 ppm. Thus, the ammonia problem may be solved by dilution (for example when untreated sewage is pumped into the sea), otherwise it must be converted into something less toxic, preferably by biological means. Fortunately there are bacteria which will convert ammonia to the far less toxic nitrite and nitrate. This solution is the one commonly adopted in inland cities of the Western world. The nitrate is very soluble and is removed from the vicinity by streams and rivers.

Conversion of NH_4^+ to NO_3^- is obviously an oxidation. In addition, human beings excrete about 100-150 g of solids each day, much of it as undigested plant polysaccharides (roughage). Microorganisms present in almost any natural water will slowly hydrolyse these polysaccharides to monosaccharides, and if an oxidizing agent is available, will convert the latter to CO_2 and H_2O .

Since marine waters are not required for drinking, or as a reservoir of dissolved oxygen, in the same way as fresh waters, even intense pollution of enclosed seas is not regarded so seriously although the disappearance of deepwater fish is an unwanted event.

OFFSHORE OIL DRILLING : Two important pollutants are mercury and oil. Offshore exploration for petroleum is increasing at a rapid rate in many parts of the world including our own country. The most significant pollution



Fig. 21. Marine Ecosystem.

incident from an offshore oil operation is an accidental oil spill where a large quantity of oil suddenly escapes into the environment. These spills may be caused by an oil well blow out, a platform accident, a large marine pipeline rupture, or

a heavily leaking tanker. In general ecological sensitivity to offshore oil and gas operations increases closer to the shore. Ecotypes such as beaches, coral reefs and many rivers along the coast play critical roles in fisheries or recreational uses. Together with this the study of the effect on marine ecosystem is also very important, (Fig. 21).

Soils and Soil Pollution

Soil forms when the weathering products interact with the atmosphere, hydrosphere and biosphere to produce a mixture of mineral matter, organic matter, air and water (Fig. 25). Apart from rugged mountains, deserts and areas of perpetual

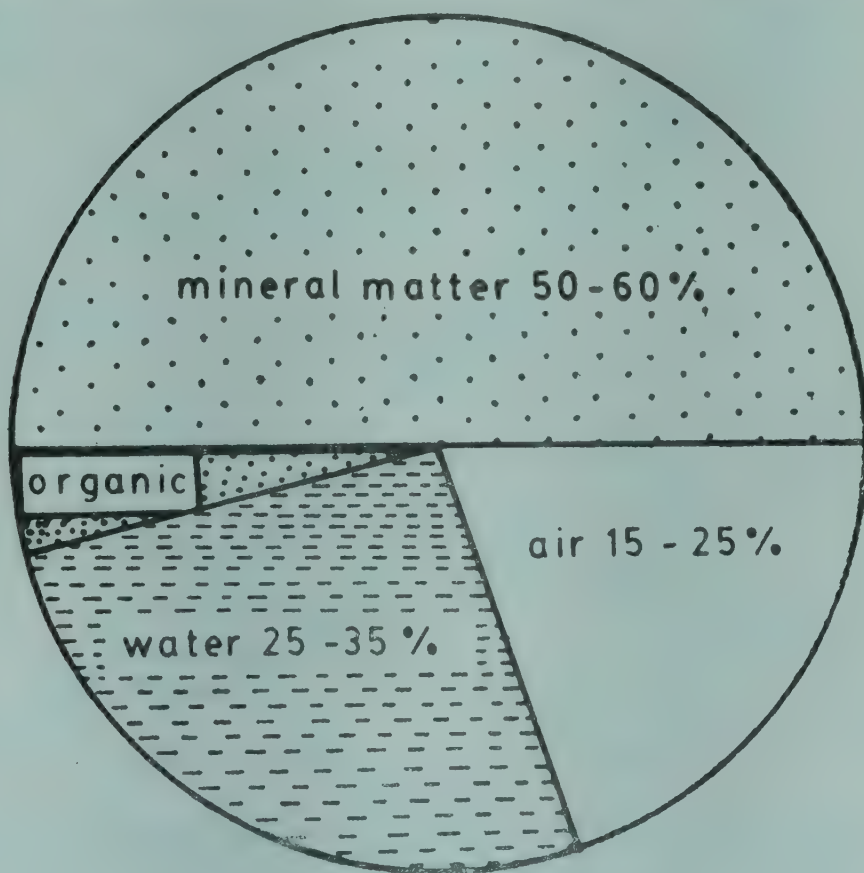


Fig. 25. Composition of soil

ice and snow, soil forms an almost continuous mantle over the land surface, ranging in thickness from a few centimetres to about two metres (Fig. 26). Although the soil

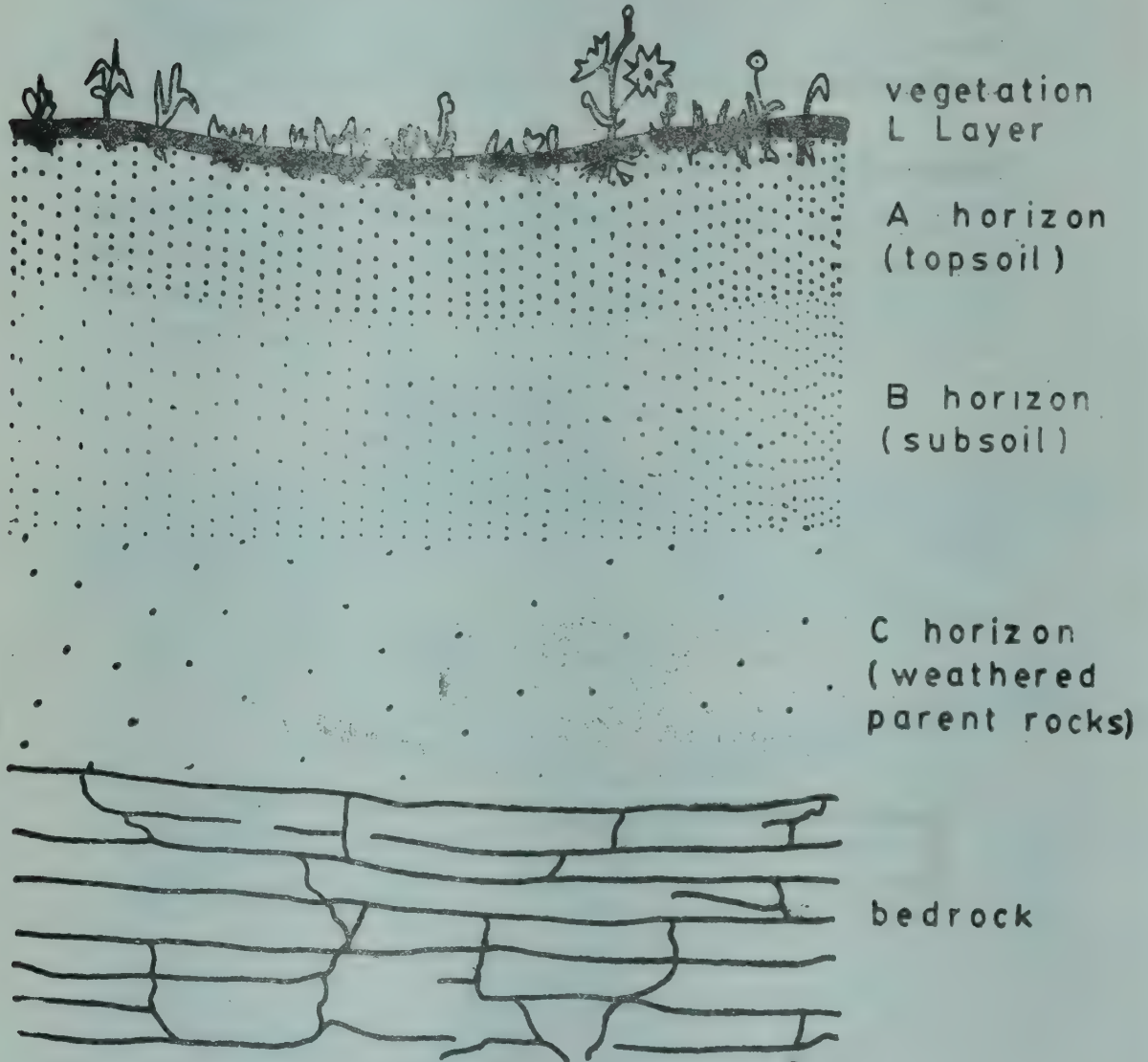


Fig. 26. Schematic diagram of a soil profile : A, B and C horizons are shown.

layer is wafer thin in the context of the whole Earth, its economic and social importance is immense and the chemical and physical properties of soil are worth studying for a variety of as well as academic, reasons.

Soil is a complex environment with microorganisms as one of its major biotic components. In this environment the activity of a few micro-flora, e.g. biological fixation of atmospheric nitrogen, breakdown of animal and plant remains into smaller compounds for plant utilisation and removal of some

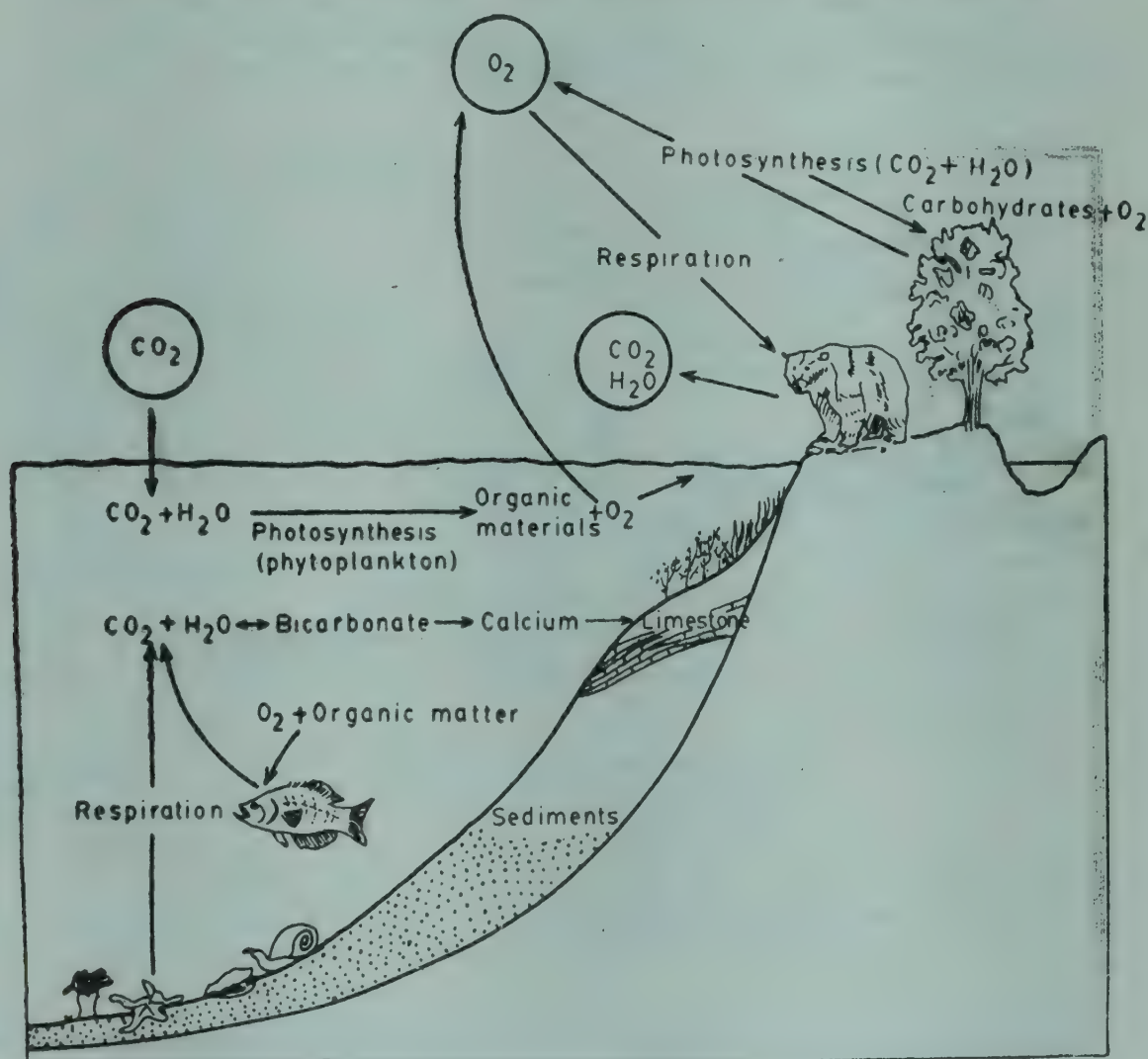


Fig. 22. The oxygen cycle. Oxygen occurs in the organic molecules of all forms of life and in water, in carbon dioxide, and in the atmosphere. Most of the molecular oxygen present in the atmosphere was provided by photosynthesising minute algae and higher plant life.

of the diverse products such as pesticides, are generally conducive to the fauna and flora.

The life supporting biogeochemical cycles, involving important elements such as carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur are removed from the environment, incorporated into structures, and eventually returned to the environment to be used over again (Figs. 22, 23, 24).

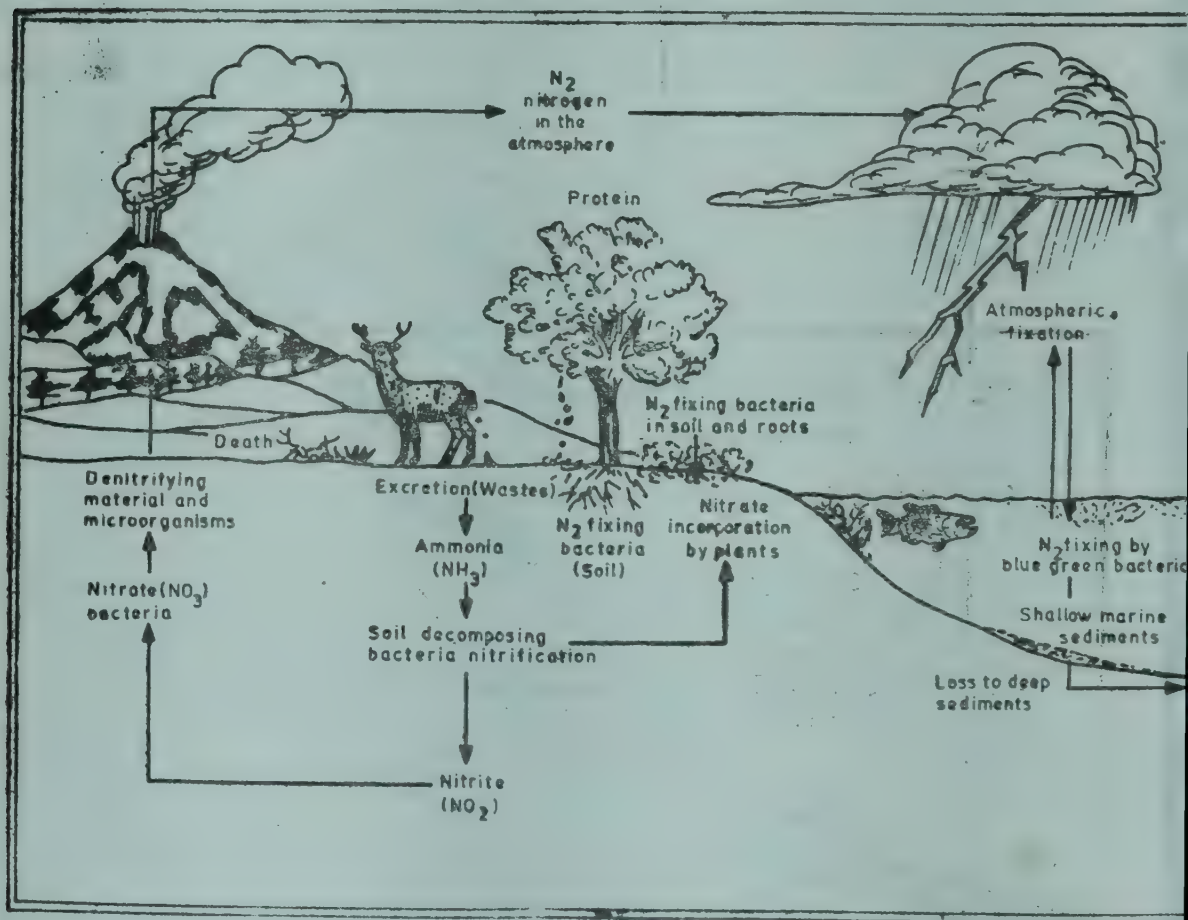


Fig. 23. Nitrogen Cycle. One of the most important microbial processes in the nitrogen cycle is nitrogen fixation, the conversion of nitrogen gas N_2 , into nitrogen compounds.

The way people study soils generally depends on their specialist interest. Thus, the farmer is interested in the top

25 cm of soil, the depth disturbed by the plough, and in the relationship between soil and crop productivity or the health of livestock; the hydrologist studies the transport of water through soils, the civil engineer studies the mechanical properties of soil, the ecologist studies the aspects of soil that

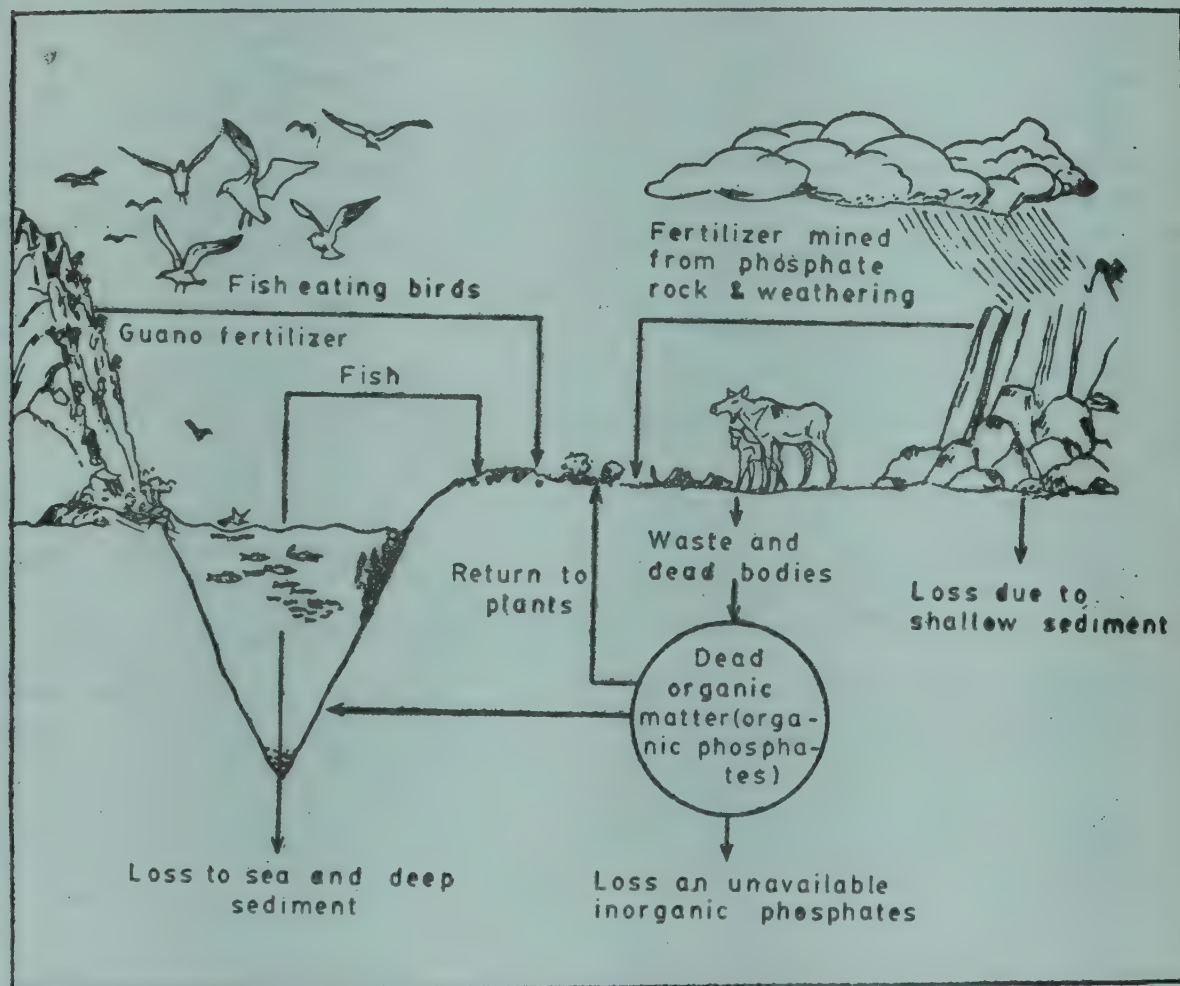


Fig. 24. Phosphorus Cycle, As water runs over rocks various minerals, including phosphates, are carried as sediments to the bottom of the sea faster than they can be returned to the land. Role of sea birds is important as they return phosphorus to the cycle in form of phosphate-rich droppings.

effect plant growth and diversity, and so on, Fig. 27 shows the chemical processes that take place in the soil environment and how these contribute to our understanding of the chemistry of the Earth's surface.

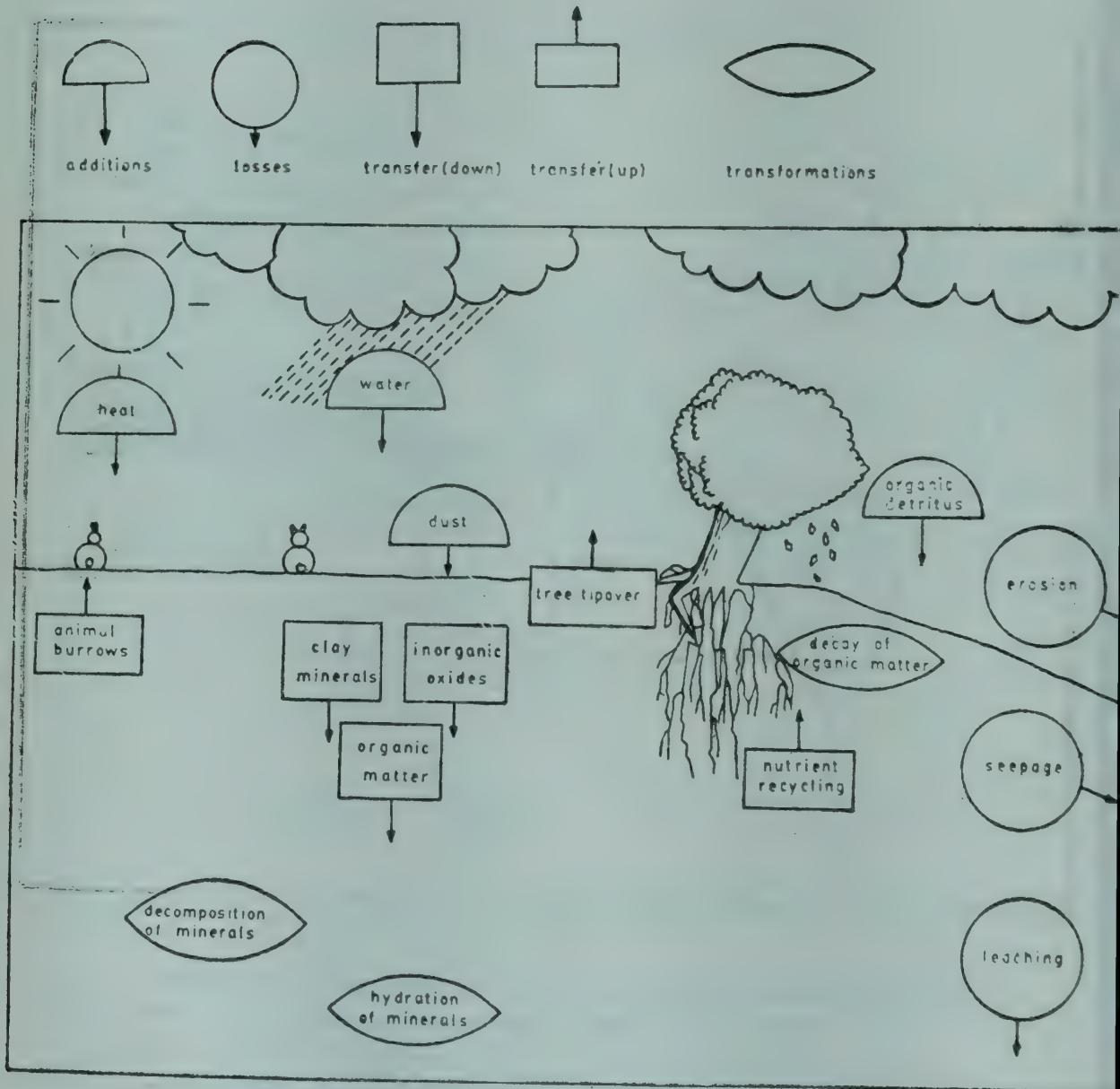


Fig. 27. Process taking place in the soil environment.

COMPOSITION OF SOIL : We have already seen that soil is a mixture of four major components : mineral matter, organic matter, water and air. The relative proportions of the components may vary considerably. In the surface layer, they generally fall within the ranges shown in Fig. 25. The profiles that result are normally divided into three main horizons as shown in Fig. 26. The uppermost of these, the topsoil, is typically 10-25 cm in thickness. This horizon contains a high proportion of organic matter from which metal ions, clay minerals and some organic matter have been leached by rain water. The underlying horizon, the subsoil, is known as the B horizon, and it is here that most of the material leached out of the topsoil accumulates. Usually there is a contrast in colour or texture between the A and B horizons. The C horizons comprises the weathered rock material from which the soil originated. Organic matter on the surface not yet incorporated into the soil is termed the L layer, and the underlying unweathered rock, if seen, is termed bedrock. Formation of soil as a result of integration of the subsoil and decomposition of the vegetative debris through the activity of micro-organism is an extremely slow process : a layer one centimetre thick may be formed in more than a century.

SOIL EROSION : By erosion is meant the removal of soil and rock material by water, wind and gravity, generally at an accelerated rate in an environment disturbed by animal life chiefly man. Soil in a forest is liable to get eroded quickly through the action of rain or wind unless it is adequately covered by vegetation.

ACID RAIN AS SOIL POLLUTANT : The signs of what Germans called 'Waldsterben' or dying forests, are obvious. The evergreens have been the most susceptible-76% of the firs are affected.

Researchers initially blamed service climatic conditions, like the near drought of 1976. Today suspicion focusses on environmental pollution, particularly the acid rain caused by

auto and industrial emissions. (West German industries burn 3.5 millions tons of coal a year leading to heavy discharge of sulphur dioxide.) According to Prof. Bernhard Ulrich, an expert on soil science at the University of Gottingen, acidic down pours can leach key nutrients, such as calcium and potassium, from the soil or deposit toxic metals like aluminium. Acid rain might also prevent microorganisms in the soil from converting organic debris into fertiliser. Along with acid rain dry air borne pesticides of metal also do the harm.

New pollution controls have been issued, limiting the amount of sulphur, nitrogen and metal emissions that can be spewed into the air from factories. Greater use of fertilisers like lime can counteract acidity in the soil also lead free gasoline.

PESTICIDES AS POLLUTANTS : Pesticides are a major soil pollutant because of the retention of pesticides in soil. Pesticides include herbicides and insecticides.

Herbicides accounts for 40% of world pesticide production, and almost 66% of pesticide usage is in highly developed countries. The three main classes are : a) uncouplers, b) agents acting on chloroplasts ; and c) auxin stimulators. With few exceptions, most of the insecticides developed in the last 3-4 decades, act on the central nervous system, usually by blocking the function of the enzyme, acetylcholine esterase. There are organochlorines, organophosphorus, organomercural insecticides. In the early years over use of pesticides was very prevalent. At higher concentrations small animals were at risk and the chlorinated hydrocarbons were leached into rivers where they poisoned fish. Some compounds are lipid soluble and accumulate in body fat, they move rapidly up the food chain, with disastrous results to birds. Biologically the most serious phenomenon was the development of resistance. Mosquitoes and houseflies are some of the most important examples which have become resistant to DDT within few years (Fig. 28). Twenty years later after the first use of DDT and other

insecticides, it has been found that almost 100 species of medically important insects and over 200 agricultural pests had developed resistance to insecticides.

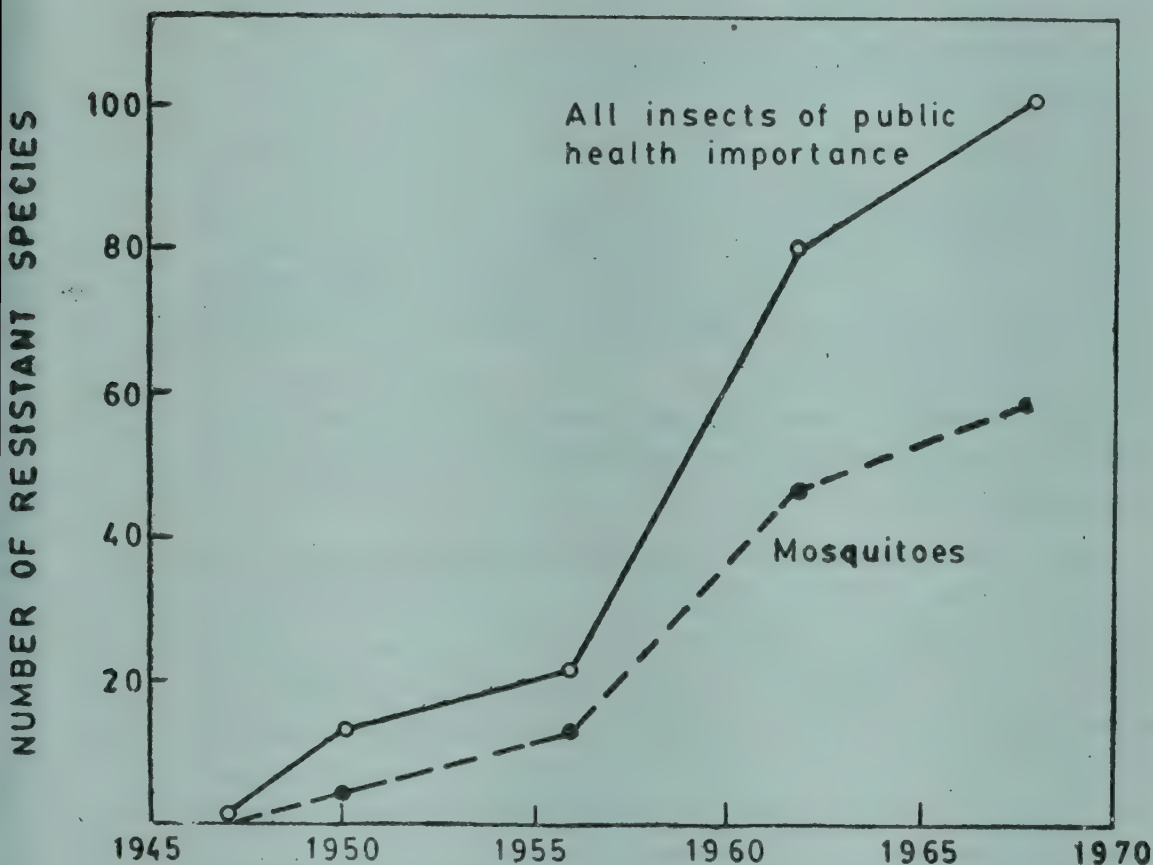


Fig. 28. The number of insects of public health importance which have developed resistance to insecticides.

Noise Pollution

Noise is usually defined as unwanted sound or sound without value. Noise as an environmental pollutant has recently become an object of serious social concern. However, it cannot be isolated from other social concerns, and is inextricably linked with the many facets of contemporary civilization;

accompanying man's essential, as well as non-essential activities and his way of life. Noise differs significantly from air pollution and also from thermal pollution, in the sense that it decays almost instantaneously and leaves no residue. Yet noise is a persistent pollutant in the many practical situations where noise sources cannot be suppressed, and it degrades the quality of life.

Continued exposure to high levels of noise can, of course, result in permanent hearing loss, and there is increasing evidence that noise may have other physiological and psychological effects. Even low levels of noise can create an environment that is unsatisfactory for human communication, work, sleep and recreation.

Noise levels increase with increasing urbanization, just as other forms of pollution are aggravated by increase in pollution density.

Noise sources have increased at a much greater rate than the population. In United States, the most important environmental noise increment, of course, has accompanied the advent of a very large turbofan jet fleet and increased truck traffic. It is estimated that 9,000,000 people living in homes covering an area of 2000 square miles are currently exposed to aircraft and highway noise levels that are deemed to be incompatible with residential living. The overall impact of noise on society cannot be assessed in simple terms. However, it is estimated that in the United States, 80 million people, or roughly 40% of the population, are subject to noise levels, that are annoying and that frequently interfere with communication, relaxation, sleep, or some other social activity. A much smaller number are subject to a potential health hazard, in terms of hearing loss, attributed solely to high level noise exposure. Solutions to the noise problem will be concerned with (1) the noise source (2) the path of sound propagation and (3) the receiver.

Despite the increase in annoyance from noise sources, it is

questionable if significant noise reduction will be achieved in many fields in the immediate future.

Because we live in a democratic society, the type of environment and the quality of life that can be realized will ultimately depend on voter consensus. Engineers can locate the sources of noise, make quantitative physical measurements of many of them, suggest acceptable standards, and estimate the cost of attaining these standards. In some instances information relative to the physiological and psychological benefits that accompany lower noise levels can be made available to the public. But communities must be aware that noise measurements and the adoption of standards alone will not solve the noise problems and that any meaningful solution will have an economic impact. Legal considerations must also be factored into any overall noise abatement goals.

5 Microbes and Environment

Bioconversion

As used here, bioconversion refers to the biological or enzymatic production of a useful product, such as methane, the degradation of petroleum products as pollutants, and the detoxification of organophosphate pesticides.

METHANOGENESIS : Methane production occurs as a normal part of the carbon and oxygen cycles. The world wide concern over dwindling petroleum reserves has focussed attention on methane as an important fuel. Methane is especially interesting because it is in essence a recyclable commodity. Various plant and animal wastes and vegetation forms have been investigated as raw material for commercial methane production. For example, an important by-product of sewage treatment is methane. A research report detailed a process of cattle waste digestion that yields nearly twenty times the methane produced during normal sewage treatment

Methanogenesis is an anaerobic process in which methanol organic acids, or carbon dioxide are reduced to methane. This occurs in aquatic sediments, black muds, marshes, swamps and in the rumen of appropriate animals. The methane-producing bacteria depend upon the syntrophic production of the necessary substrate, including hydrogen, in these habitats. In fresh water sediments, acetate is a major substrate and nearly pure methane has been collected at a slow but consistent rate in Lake Erie in the United States. In salt marshes along the southeastern coast of the United States, hydrogen and formic acid were found to stimulate methano-

genesis. Ruminants are also known to have a system in which carbon dioxide and hydrogen are important substrates in methanogenesis, since the organic acids produced by fermentation in the rumen are absorbed by the animal for its own nutrition.

Typical methanogenic bacteria are *Methanococcus* spp. in rumens, *Methanosarcinia thermoautotrophicum* and *Methanospirillum hungatii* in sewage sludge and *Methanobacterium arbophilum* in the wet wood of a living tree.

PETROLEUM OR HYDROCARBON DEGRADATION:
The degradation of crude oil materials is a major ecological concern. It was estimated in 1971 that 1.2 million metric tons of petroleum pollute marine environments each year as a result of spills by tankers or wells or as a result of the cleaning of tankers while they return to load more cargo. Crude oil is a complex mixture of hydrocarbons containing paraffins, kerosene, octane, petroleum oils and many other components. The fact that oil spills eventually disappear from waters, soil around refineries, leaky pipelines and polluted beaches is clear evidence that microorganisms can decompose these hydrocarbons. A species of *Corynebacterium* has been isolated that can oxidize paraffin in a manner comparable to fatty acid catabolism to acetyl CoA. *Pseudomonas putida* strains from terrestrial and aquatic habitats have been shown to oxidize benzene, toluene, ethylbenzene, octane, naphthalene, camphor and salicylates as sole sources of carbon. Metabolic plasmids control many of the hydrocarbon-degrading enzymes in these organisms.

Petroleum degrading microorganisms adsorb oil droplets. The smaller the droplets, the greater the ability of the organisms to oxidize the substrates and reproduce. These organisms also have the ability to produce emulsifying agents that help from small droplets. Yeasts such as *Candida tropicalis* produce cell wall material of mannan and fatty acid, which assists in droplet formation. Most organisms excrete some form of extracellular material for this process.

Although oil-degrading microorganisms have been found in varied habitats, including arctic coastal water, their use to inoculate oil spills has proven ineffective. The major problem appears to be the low level of nitrogen and phosphorus compounds in sea water. One solution that has been tried is to treat urea and octyl phosphate with paraffin to produce a slow release fertilizer. This material distributed with the organisms in powder form, appears to promote microbial action.

Although the prospects for using microorganisms to clean up oil spills is encouraging, it must be kept in mind that micro-organisms can also cause spoilage and deterioration of petroleum products. Species from the bacterial genera *Pseudomonas*, *Chromobacterium*, *Alcaligenes*, *Mycobacterium* and *Sarcina*, as well as certain fungal species of *Aspergillus* and *Monilia*, can decompose gasoline. In addition, the deterioration of asphalt highways and pipe coatings has been caused by species of *Mycobacterium* and *Nocardia*.

PESTICIDES AND MERCURY : The pesticide parathion belongs to a large group of chemicals known as organophosphates. These compounds are extremely toxic to insects and all other animals because they prevent nerve cell conduction across synapses. They are so effective that they have been tested extensively for use as nerve gas. In a study relating to the concept of microbial infallibility, various soil sewage microorganisms were tested for their ability to detoxify parathion. Mixed bacterial cultures were found to be effective in preliminary studies. Some of the organisms involved were species of *Brevibacterium*, *Pseudomonas* and *Azotomonas*.

The chlorinated hydrocarbons, which include DDT, aldrin, DDD, lindane, and endrin, can be 'degraded' under anaerobic conditions by various facultative anaerobic bacteria and yeast, but the end products are still extremely toxic. In one study, it was observed that DDT (dichloro-diphenyl trichloroethane), was dechlorinated to form DDD (dichloro-diphenyl) dichloro-

ethane), another very toxic pesticide. The problems associated with the build up of chlorinated hydrocarbons in various aquatic and terrestrial environments appears to be related to their relative hardness to attack by microorganisms.

Another problem pollutant in terrestrial and aquatic environments is mercury. Mercury is toxic to humans and other life forms, as demonstrated by the mercury poisoning tragedy that occurred in Minamata Bay, Japan, where industrial pollution produced exceptionally high mercury levels in their fish. The form of mercury in the fish was methyl mercury, which is 50 to 100 times more toxic than inorganic mercury compounds. The methylation of mercury can occur abiotically, but considerable evidence points to a significant role of many bacteria and fungi in this reaction. Some organisms, such as *Clostridium cochlearium*, introduce a methyl group on the molecule cobalamin by using vitamin B₁₂ and cystine. Subsequently, the methyl group can be transferred to mercury nonenzymatically. *C. cochlearium* is anaerobic, performing the methylation in aquatic bottom sediments and sludge. The ability to methylate mercury has been shown to exist in indigenous microorganisms such as species of *Pseudomonas* on the gills and in the intestines of fish. Aerobic methylation also occurs. Soil organisms with this capacity include a species of the bacterial genus *Pseudomonas* and the yeast *Neurospora crassa*. One source of mercury in soils has been the application of organomercurial fungicides. Research in Sweden since the introduction of these fungicides has shown considerable increases of methyl mercury in plant and animal tissues.

Bioconcentration

Bioconcentration is the ability of microorganisms to store materials in the environment. The storage may be within cells, as in the case of sulfur, or outside the cells, as in the case of nitrate or sulfur. The metabolic activities of sulfur

oxidizers have been used to concentrate low grade mineral ores. Sulfur oxidizers, such as *Thiobacillus*, can grow in slag from coppermines, the material remaining after ore is roasted to remove most of the copper. The sulfuric acid produced by the growth of *Thiobacillus* dissolves the copper, sulfate accumulates at the base of the slag pile. A similar process is used to concentrate uranium from ores in the form of uranyl sulfate. Bioconcentration has caused the formation of commercially attractive deposits of manganese but also hazardous accumulations of pesticides and radioisotopes in nature.

MANGANESE DEPOSITS: Manganese, an important element in plant nutrition, is found widely distributed in terrestrial and aquatic environments. It is commercially important in alloys of iron, aluminium, and copper. In the soil, bacteria such as *Leptothrix* (*Sphaerotilus*) *discophorus* oxidise manganese compounds and accumulate manganese dioxide (MnO_2) in their cells. This oxidation may be a primary energy source for these organisms. The accumulation depletes the manganese available to plants until reducer organisms render MnO_2 deposits soluble and available once more.

In the oceans, both of these reactions have also been noted. A species of *Arthrobacter* has been found associated with ferromanganese nodules. These nodules contain as much as 63 percent MnO_2 deposited by the oxidative capacity of the bacteria. A species of *Bacillus* isolated from nodules and deep sea sediments can reduce MnO_2 as a stage of its electron transport system. The reduction process must be significantly slower than that of oxidation or the nodules would not have formed to the extent that has been observed. International discussions have been held on cooperative ventures for the mining of these nodules.

PESTICIDES AND RADIOISOTOPES: In 1976 the United States Council on Environmental Quality reported an incident involving the chlorinated hydrocarbon kepone. A



snow-covered Himalayan peaks of Jamunotri.

*Fir, Chir, pine and
other trees on the
mountain slopes—
the roots hold the
soil.*



*The pines are high
and mighty.*





The temple of Lord Kedarnath about 12,000 feet above sea level.



Gaumukh (Cow's mouth) Glacier from where the Ganges emerges. But man tramples nature—hence he plants his 'lathi' and 'jhola' to indicate his victory.



The Ganges drops through a tremendous height at Gangotri.



Ganges flows into the Bay of Bengal through the Sunderbans, where the mangrove, coconut palms and narrow canals abound.



Nature's painting—a kind of small bamboo on the slopes.



A flock of sheep at Uttarkashi—going down at the onset of winter when the pastures at higher altitudes remain snow-covered.



A crocodile reared in a 'crocodile farm'.



A cheetah in a zoo.



A mother-bird in her nest.



A monkey on the bridge—at Lachhmanjhoola, Rishikesh.

foreign company had been making kepone for sixteen months and cases of poisoning in their personnel had been linked to kepone. When the United States Cancer Institute reported animal studies showing kepone to be carcinogenic, the company was required to stop making the pesticide. Evaluation of the environment, including some river, showed that water and shellfish contained traces of the chemical as far away as 40 miles. It is suspected that the kepone accumulated in microorganisms, upon which the shellfish feed.

More definitive examples of the accumulation of toxic substances have been reported for radioisotopes, which have also been shown to be carcinogenic. In "the Myth of the peaceful Atom", by Curtis and Hagan two pertinent examples are presented. The Savannah River Nuclear Power Plant in Aiken, South Carolina, released "insignificant" amounts of radioactivity in its cooling water. An examination of algae in the water, however, showed a concentration up to 6000 times the level in the water itself. These algae serve as food for the bluegill fish, the bones of this fish had a concentration 200 times that in the water.

The Hanford Nuclear Power Plant in Hanford, Washington, used the Columbia River for cooling water. As suspected, the water there, too, had "insignificant" levels of radioactivity and was considered "safe". Algae and other microorganisms in the water concentrated this safe level of radioactivity as much as 2000 times. Fish who fed on the plankton had levels of 4000 times that in the water, while their egg yolks had concentrations of one million times that of the safe water. Clearly one aftermath of the failure of the Three Mile Island Power Plant in 1979 that will be closely followed by scientists is the bioconcentration of radioactivity in the plant and animal life in and around the Susquehanna River. These few examples of bioconversion and bioconcentration of toxic materials in nature should serve not only to render the concept of microbial infallibility suspect, but also to stop our reliance on

aquatic and terrestrial habitats for the dumping of waste materials.

TABLE VII. *Three Abiotic Factors and Selected Microorganisms that Grow Under Extreme Conditions in Nature*

Abiotic Factor	Microorganisms	Condition for Growth
Temperature	<i>Blue-green bacterium.</i>	73°C
	<i>Thermoactinomyces spp.</i>	68°C
	<i>Rhodotorula sp.</i>	14°C
	<i>Flavobacterium spp.</i>	4°C
	<i>Bacillus globisporus.</i>	-10°C
pH	<i>Agrobacterium sp.</i>	12.0
	<i>Vibrio cholerae</i>	9.0
	<i>Bacillus pasteurii</i>	8.5
	<i>Sulfolobus sp.</i>	0.5
	<i>Thiobacillus thiooxidans</i>	0
Osmotic	<i>Candida spp.</i>	60% sugar
Pressure	<i>Hansenula spp.</i>	60% sugar
	<i>Saccharomyces spp.</i>	60% sugar
	<i>Sarcina morrhuae</i>	27-30% NaCl
	<i>Halobacterium salinarum</i>	27-30% NaCl
	<i>Pseudomonas cepacia</i>	Distilled water

Impact of Pollution on Environment and Society

As the Society attains a high enough scientific and technological level, a host of complexities emerge in the relations between society and nature mostly created by man. Nature was regarded as an inexhaustible treasure house and it was thought that nature's riches could be exploited without giving thought to the problem of how they could and should be extracted and utilised. In their discussions on the problem of environmental protection scientists and political leaders and public spokesmen in many countries have noted, as a major feature, the global universal character of this problem, which concerns all the contries and peoples inhabiting the Earth. It was this realisation of mankind's common destiny in the face of ecological problems, i.e. problems connected with preserving all forms of life on our planet that makes us ponder over the Earth's valuable reserves of air and soil, water and the natural resources.

The degaradation of the environment is borne out most strikingly by atmospheric pollution, which is especially dangerous to human life and activities. Various types of industrial activity increase the contents of gaseous and solid substances in the atmosphere. This can have as indirect results such phenomenon of danger to men as an oxygen shortage, a rise in the viability of viruses causing respiratory and bronchial diseases, and the growth of the microbe population of the atmosphere. The state of our planet's water resources, especially the resources of fresh water, is another cause of growing concern. The total amount of fresh water in all the

rivers of the world is estimated at 1,200 cubic kilometers, and this amount is renewed nearly 32 times a year. Besides, there are the reserves of underground water (approximately 60 million cubic kilometres) and the sea water of the world ocean (over 1,370 million cubic kilometres). At first glance, these figures seem quite impressive. But the intensive use of water for various industrial, agricultural, and other needs has appreciably worsened its quality in a number of rivers, and areas of the seas and oceans. The annual worldwide discharge of sewage at the beginning of the 1970s reached 440 cubic kilometres, and this affects the quality of a 15 times greater amount of fresh water, which exceeds one third of the total fresh water runoff in the world.

Out of the total amount of 5·10⁸ tons of diverse industrial, agriculture and municipal wastes released into the biosphere every year, a considerable amount goes into various bodies of water. This causes fish and other living organisms to perish in rivers, lakes, and the coastal waters of seas and oceans, which is only one of the processes reducing the diversity and population of the animal world of our planet as a whole. The extermination of wild animals by man began several centuries ago and steadily gathered momentum. In less than 2000 years many species and strains of mammals, not to mention birds and other animals, have vanished. Whereas the first 33 forms of mammals disappeared in 1800 years, the next 40 vanished in a mere half century. According to the data of UN experts for the latter half of 1975, 106 species of animals and 139 species of birds have been wiped out in the past 20 centuries through ecological ignorance and, at times, barbarism. Another 500 species, whose evolution in natural conditions took millions of years, are now on the verge of extinction. Biologists estimate that one species of animals now vanishes completely every year. The once enormous herd of bison has been almost completely wiped out. So has one of the most numerous species of birds in North America, the passenger

pigeon. Blue whales too are almost extinct. The list of these sad examples could be continued.

In the Earth's atmosphere there is a build up of carbon dioxide. It is estimated that our planet's vegetation every year combines 150,000 million tons of carbon dioxide with 25,000 million tons of hydrogen to produce 450,000 million tons of organic substances with the release of 400,000 tons of

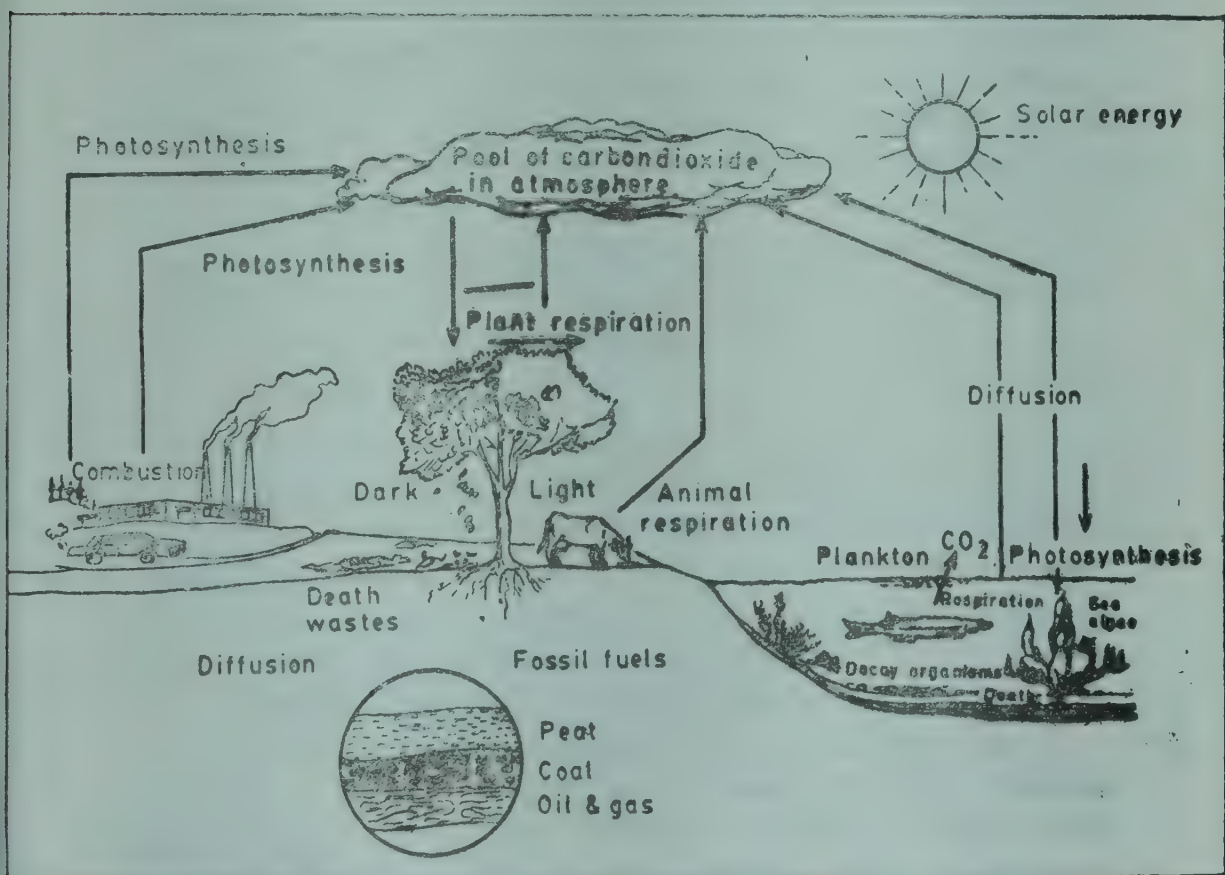


Fig. 29. The biogeochemical cycle of carbon. Energy from the Sun is used by higher plant life, algae, and various microorganisms to convert carbon dioxide and water into organic compounds. Eventually these compounds are decomposed to form carbon dioxide again and release it into the atmosphere. Various microorganisms are involved in the process of decomposition in this cycle.

oxygen. Whereas in the early stages of the development of society the carbon dioxide released into the atmosphere was generated primarily by the vital activity of animals and man, and also by hot springs and volcanic eruptions, at present much of it comes from society's economic activities. The burning of fuel and natural resources alone releases no less than $1 \cdot 10^{10}$ tons of carbon dioxide into the atmosphere every year (Fig. 29). It follows from the estimates of scientists that considerable amount of carbon dioxide (approximately $1 \cdot 10^{11}$ tons) is in a state of exchange between the atmosphere and the World Ocean. Disturbing data were, however, obtained in the 1960s to the effect that the biosphere of our planet is no longer able to neutralise the build up of carbon dioxide in the atmosphere. During the 10 years that ended in 1973 the carbon dioxide content rose 0.2 per cent a year owing to man's industrial and other activities. Scientists fear that the continued growth of the carbon dioxide content even at such a rate could raise the temperature of the Earth's atmosphere.

Experts in many countries have been drawing attention to the rise in the thermal energy released into the atmosphere through man's industrial activities: the industrial burning of various fuels, the atomic power industry, transport, etc. Early in the 1970s the "added" heat generated by the activities of human society amounted to only 1/15,000 of the natural heat coming from the sun and from the interior of the Earth.

But according to the forecasts made by the experts the amount the heat generated by artificial sources—assuming that society increases its energy consumption at the present rate—will in 250 years have reached 100 per cent of the thermal energy reaching the Earth from the Sun. This would raise the temperature of our planet by 50°C , creating conditions unsuitable for human life on Earth.

In recent years there have been many studies of the character and probable consequences of various global effects of human society upon the biosphere, the climate and the wea-

ther, the ozone layer around the Earth, etc. Without going into the specific results of these investigations, it is necessary to recognise, first and foremost, that such problems exist and are a logical consequence of the development stage that civilisation has attained. As they are studied more and more profoundly, states will begin to tackle them from the standpoint of protecting the biosphere and establishing a global ecological balance. As for various pessimistic predictions which are made on the strength of one-sided and at times hasty conclusions by some investigators, their inherent weakness lies in their disregard for the potentialities of human society in purposefully and rationally transforming not only its natural environment, but its own activities, as ecological problems grow more acute.

Desertification and Arid zones

In many ways the term desertification is misleading. The main cause is not drought (drought tends to exacerbate the problem), but human over exploitation of lands through over-cultivation, over grazing, poor irrigation practice and deforestation.

In general, the earth's arid regions lie in narrow belts which straddle the Tropic of Cancer and Tropic of Capricorn. In these areas, the prevailing winds are very dry since they have lost their load of water farther to the north or south. The

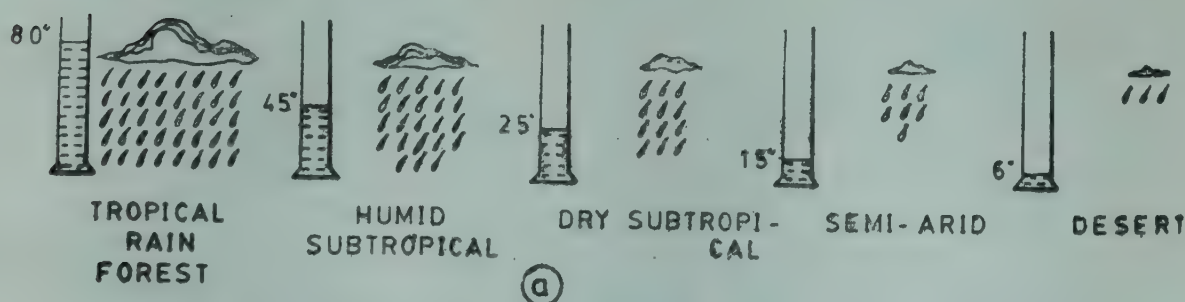


Fig. 30. (a) Annual rainfall in five different climatic zones of the world.

common characteristic of all deserts is aridity, which is generally defined as an annual rainfall of 10 inches or less (Fig. 30a). In addition to sparse rainfall the deserts are characterised by high heat. Their low humidity lets the sun-rays penetrate the atmosphere and warm the ground to an extent

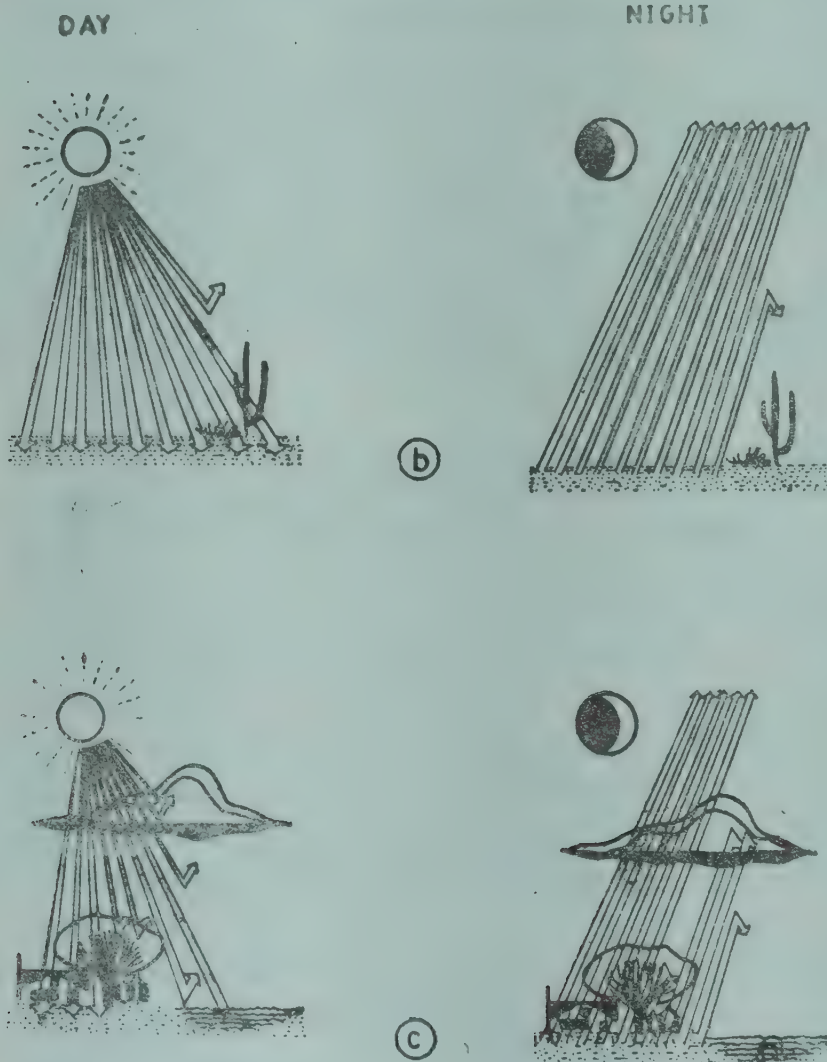


Fig. 30. (b) Desert region during day and night.

(c) Humid region during day and night.

By day, desert regions take in more heat than humid regions. At night, deserts turn cold, humid lands remain moderate.

that is impossible in moister places. The common summer temperatures are 50°C — 58°C . But low humidity of typical deserts allows their day time heat to dissipate quickly at night. After a blazing summer day the temperature may drop 28°C or more. The desert's night coolness is an important factor in the survival of plants and animals (Fig. 30b and c). In the unique desert environment highly specialised forms of plant life have evolved, adapting themselves in one way or the other to the drought that for ever threatens their existence.

The desert animals have adapted to survive drought too, but more often by a change of habit than by altered structure.

Some deserts of the world are shown in the map (Fig. 31). The great Indian Desert is the Thar which lies to the east of the Indus River.

7 Forest Ecosystem

Environmentalists are worried over the ill effects of increased burning of fossil fuels and of late of firewood without matching the cut with equivalent plantations. Such burning emits carbon dioxide and changes the temperature pattern of the atmosphere by diffusion of heat into space, a phenomenon known as "green house effects". The one agency which can minimise the ill-effects of accumulated carbon dioxide is ample vegetation, hence the need for forests which absorb it by photosynthesis and make carbohydrates. The accumulation of carbon dioxide is increasing at an alarming pace and therefore pollution, as more and more vegetation is being removed. A well-stocked eco-system exercises considerable beneficial effect on human environment by moderating the climate, maintaining the soil mantle, regulating the water supplies, purifying the air and helping in abating noise. It also has an aesthetic value.

A forest and its environment are always interacting. The most important environmental factors are micro-climate, soil characteristics, moisture-availability and action of animals and insects. Micro-climate is governed by solar radiation, rainfall, wind, humidity and temperature of the air and the soil. In a dense forest temperature range is narrow and although the air temperature in and outside a forest is more or less the same, the humidity is greater inside. Soil temperature is also influenced by the forests, which in turn affects the biological activity in the top layer of the soil. Forests also stem the wind velocity. It is for this reason that shelter-belts and wind-breaks are planted to protect crops. Heavy

winds may actually cause a serious erosion if the soil is dry and not covered with vegetation. As far as rainfall is concerned there is no evidence that the creation of a forest even over a fairly large tract of barren land increases the rainfall of the locality. But it is a fact that a forest makes the temperature equable both inside it and in its outskirts. Extensive forests also condense low clouds and thus to some extent increase precipitation.

With run-off increasing, water level in rivers rises rapidly. When water has a heavy silt-load and land is comparatively flat, rivers may change their courses and in doing so cause heavy damage to cultivated fields and other property. Soil run-off is heavy wherever there is an unrestricted browsing by goats and a ruthless removal of vegetation (overgrazing). On the other hand silt-load of streams is low wherever grazing is controlled and vegetation cover is not broken by indiscriminate fellings. Hence the need for scientifically managing the forests in the catchments.

Forests consume large quantities of water. The water is absorbed by the roots, rises with the cell-sap and is finally lost through transpiration by the leaves. Rain water obstructed by crowns of trees is also lost by evaporation. The aggregate loss through evapo-transpiration for a well-stocked teak forest is the equivalent of about 1000 mm. of precipitation. Indeed, a forest loses more water in this way than through ground, but it is still a more economic cover than other types of vegetation. Forests also add to the beauty of the landscape, make the climate salubrious, and provide a suitable habitat for the wild life.

Social Forestry

Historically speaking the forest policy has been to cater more to the demands of the industry rather than considering forest primarily as a national asset and a conservator of soil and water. The necessity of cooperation of rural population

in conservation of forests and afforestation has not been so far recognised.

It is not correct that the energy needs of the rural poor are the major cause of deforestation. They depend mainly on twigs, branches, crop waste and residues, to meet their energy need, and this seldom leads to vegetative destruction. The major cause is the illegal felling by timber contractors to meet the needs of urban markets and paper mills.

The programme of Social Forestry for rebuilding forest resources with community participation in the protection and management of forests has come into being because of this continuous depletion of forests due to demand for timber, fuel, paper production, acquiring forest land for agricultural production without corresponding replantation etc.

THE CHIPKO MOVEMENT : The 'Chipko movement' is an instance in point. In the year 1970 Gopewar (Garhwal) and scores of neighbouring villages were devastated by a flash flood in the Alakananda river. There was clear evidence that the floods had been caused by man-made erosions and that if this erosion continued, it would ultimately wipe the hill people off, literally. "Every one knows the Himalayas are deteriorating, but few realise that they are not falling apart on their own but because of our interference with fragile ecosystem in the name of development. For years large scale felling has continued without paying heed to consequences. Explosives used for road construction have shaken up mountains. Forests have been ravaged by construction crews. The rising population has also hastened the denudation process. When strong showers fall on the denuded slopes they wash away the loose soil cover. Only trees can hold the soil cover." There are the words of Shri C.P. Bhatt, the leader of the 'Chipko movement'. "We will embrace (Chipko) the trees. If they want to cut them their axes will first have to fall on us" (Fig. 32). This was told to the forest contractors in March 1973 who came to Reni Village near Tibetan border to

fell trees. The contractors had to turn back. Thus the tree hugging programme spread spontaneously and several regular 'ecodevelopment' camps were organised. Aims and objectives of Social Forestry are to transform unproductive or unutilised wastelands into abundant reservoirs of solar energy through the production of high yielding, rapidly growing, biomass, with involvement of society at all levels for its own benefit.

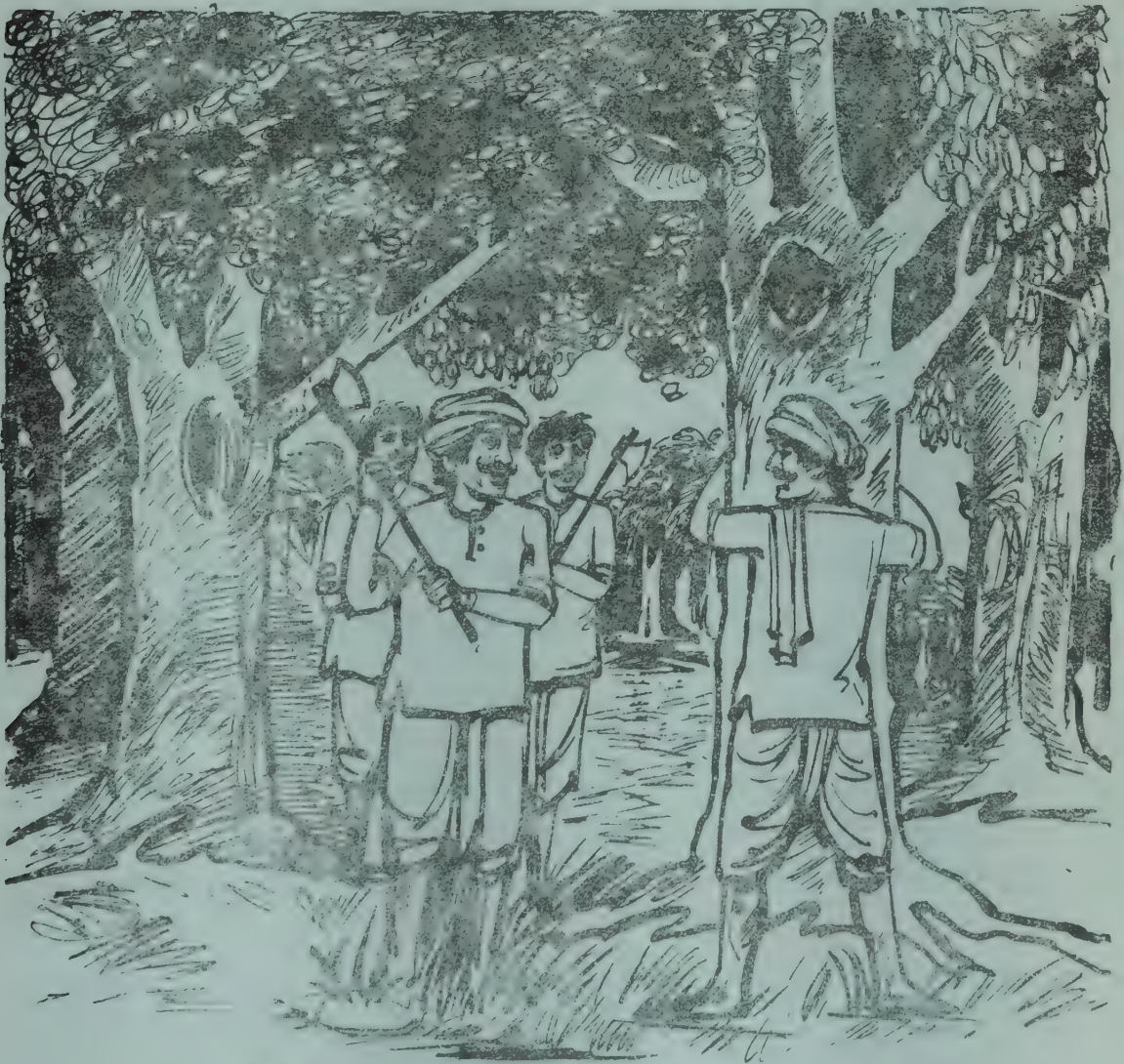


Fig. 32. The 'chipko' movement was started to stop indiscriminate felling of trees. Trees are our very valuable assets.

The specific objectives laid down by the National Commission on Agriculture in its interim Report on Social Forestry in 1973 are the following : 1) supply of fuel-wood to rural areas and replacement of cowdung ; 2) supply of small timber ; 3) supply of fodder ; 4) protection of agricultural fields against wind ; and 5) recreational needs.

I. Farm Forestry

- (i) to raise rows of trees on bunds and boundaries of fields and plant individual trees in private agricultural lands.
- (ii) to serve as windbreaks.

II. Extension forestry includes.

- (i) mixed forestry i.e., fruit trees, fodder trees, trees having fuel value, grasses on suitable waste lands, etc :
- (ii) shelter belts ;
- (iii) plantations of different quick growing species in conformity with the environment on lands on roadsides, canal banks and railway lines.

III. Reforestation in degraded forests.

IV. Environmental forestry, especially in catchment areas of irrigation dams.

8

Some Important and Endangered Ecosystems

Tropical Rain Forests

Tropical forests are an important renewable resource, acting as a reservoir of genetic diversity yielding a continual supply of forest products if managed properly. If tropical forests are exploited with little regard for their ecological characteristics, the resource cannot renew itself. Tropical rain forests are contracting rapidly as a result of expanding shifting agriculture, cutting for fuel and logging, planned projects such as hydel etc. The most valuable and richest in species are lowland rain forests which are being destroyed at a much faster rate throughout the world. Many, like the lowland forests of South East Asia, are believed unlikely to survive (in terms of area) to the end of this century.

For millions of years the tropical rain forests of South East Asia, South America and Africa have been the earth's natural chemical laboratories, botanic gardens and zoos. Today, we are destroying them at such a rate that within a few years only fragments will remain of the vast forests of Malayasia, Indonesia and India in Kerala—the now famous Silent Valley. Because they grow mostly in poor tropical soil relying upon a natural cycle between trees and animals for nourishment and replenishment, the forests cannot be replaced.

SILENT VALLEY : In the Silent Valley project in Kerala the perceptions of the provincial electricity department and those of the conservationists varied significantly. For enough good reasons the government in this case wanted to increase power

generation in the region. As there were no coal deposits they considered hydro-electric power as a cheap source of energy, and have ignored the ecological diversity of the area without giving a thought to its significant value.

On the otherhand conservationists strongly objected to this project being executed ; they showed that the area is unique and supported diverse flora, fauna and rare germ-plasms not found elsewhere in India. The power needs, they pointed out, could be safely met from other sources of energy.

When the trees are felled soil erosion begins and within a few years, the whole area, once forest becomes wasteland. If this trend, continues we shall forever lose the earth's greatest treasure house of plants and animals, perhaps our most valuable natural resource for the future. It is, perhaps, the World's most urgent conservation problem. The destruction is happening through ignorance, short sightedness and ever increasing consumer demand.

Himalayan Ecosystem

DOON VALLEY : This is another instance of ecodegradation due to lopsided planning. The high grade limestone which is found in the Mussoorie hills of the Doon Valley, is often pet named the white gold. The strip-mining and quarrying of this white gold deposits generate massive employment potential. But the activities result in a high level of pollution which would prove hazardous to the health of the locals. The lush vegetation of the beautiful Himalayan Valley faces destruction. Several surveys have shown the drastic decline in agricultural production, number of cattle etc., in the areas touched by the strip-mining and quarring. This inevitably will have far-reaching repercussions on the nutrition and health standard of the villagers. A comprehensive understanding of Himalayan ecology and economic upliftment is necessary for the overall development of the region.

THE NEORA VALLEY : The Neora is a small hill stream in the Kalimpong subdivision of North Bengal, rising from near the trijunction (3200m) of West Bengal, Sikkim and Bhutan and flowing southward for about 58 kilometres before emerging on the plains of the Jalpaiguri district near Gorubathan. It is fed by nine main streams and sixteen subsidiary streams. Neora and its main feeder, the Thosam Chu, lie enclosed in the valley formed by two roughly parallel north-south ridges, the Pankhasari ridge to the west and the Thosam danda to the east. The east-west ridge connecting these ridges at their northern end is dominated by the Rechi La (3414m). A subsidiary ridge running south from Rechi La divides the upper basins of the Neora and the Thosam.

The singular thing about Neora valley is that its dense primaeval forest cover and difficult terrain have, as far as is known, prevented anyone from traversing it. It might sound incredible that a valley in West Bengal should remain unperetrated by man in this age, but in fact the Neora valley has this rare distinction, along with one or two valleys in the remote areas of Arunachal. In addition to this, the area is of great ecological interest. The Neora valley falls under eleven forest blocks of Kalimpong (Special) Forest Division, covering an area of 16×13 hectares, of which 69 % is estimated to be primaeval forest area. This makes the Neora valley one of the best preserved biomass in India. The plan of the State Government to utilise these streams for the supply of water to the region should be carefully executed without upsetting the ecosystem of the region.

“The terrain of the valley is the usual one for short, steep (the Neora drops 3300m in about 25 km sub-Himalayn valleys a complex of gorges, ravines and spurs, all under dense cover. Geologically the rocks of the Neora area are mainly metamorphic much folded and faulted, with older formations superposed on younger ones. No important mineral occurrences are known. Rocks are

of varying ages, the main types being slates, quartzites, schists, Darjeeling gneiss, white felspar and white and brown mica. (Report from 'Himavant' Oct. 1983)".

Mangroves and Estuarian Ecosystem

SUNDERBANS : Mangroves are salt-tolerant, woody plant communities with associated fauna that occupy the tropical tidal zone. They are productive ecosystems that receive nutrients and fresh water from land, and export to the sea materials that are important to near-shore shell fish and finfish populations (Fig. 33). Estuaries may be defined as localities where river-water is incorporated into the oceans by mixing with sea water. They also serve as protective nursery areas

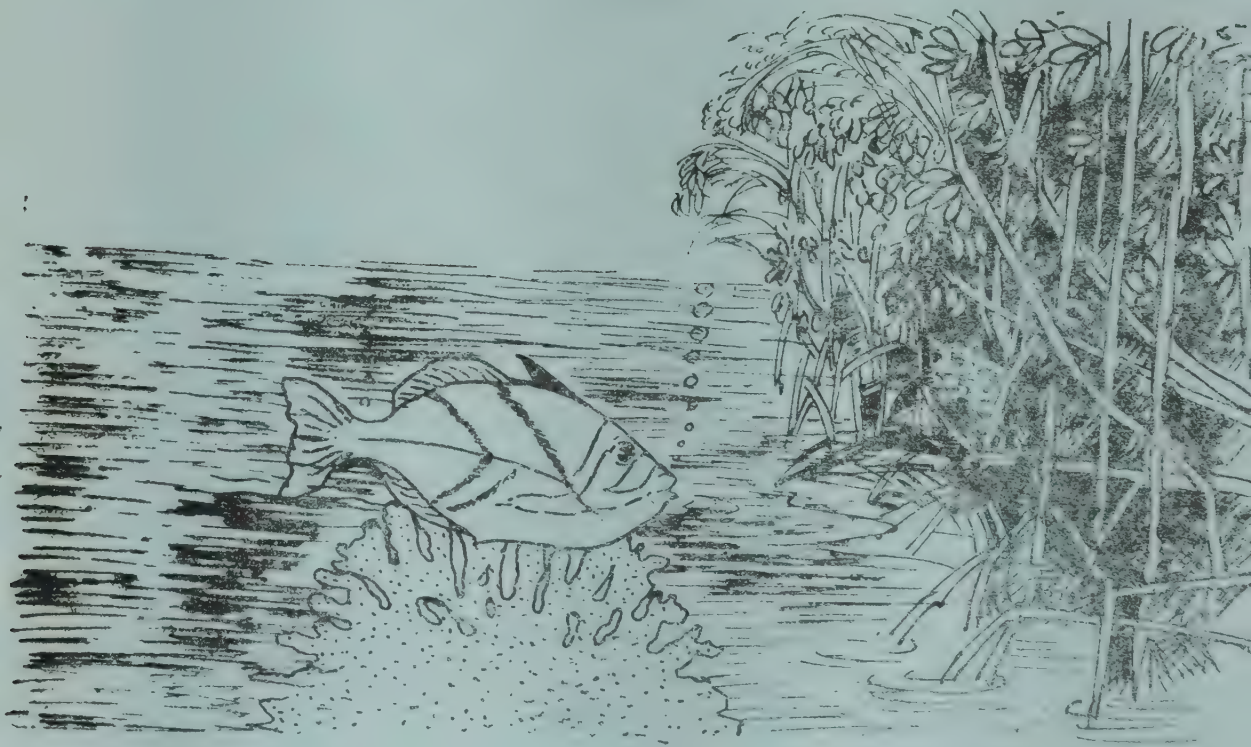


Fig. 33. Mangrove region—Sunderban in West Bengal is an example.

for many marine organisms. They are very vulnerable to human induced changes in salinity and to pollutants such as oil which coat the breathing roots and mud sediments. The Sunderban areas in West Bengal is one such ecosystem which besides many other objects is the natural habitat of the world famous Royal Bengal Tiger. The forest also has other fascinating wild life including the jungle cat, cheetal or axis deer, wild pig, rhesus monkey, mongoose and largest estuarine crocodiles in the world.

The tiger population which dwindled to about 75 just before the forest was declared as a tiger project area about 12 years ago, increased to 264 in 1983.

The Sunderban will find a place in the list of world heritage being prepared by UNESCO.

Marine Ecosystem

ANTARCTICA AND THE SOUTHERN OCEAN: Antarctica and the Southern Ocean are defined as all land sea south of the Antarctic Convergence (the well-defined but fluctuating line where the cold surface waters of the Southern Ocean sink beneath the warmer waters of the cold-temperate Atlantic, Indian and Pacific Oceans).

The continent was first sighted in 1820 by Nathaniel Palmer, an American navigator. Scientific exploration started in the early part of the 20th century with teams of scientists looking for the magnetic South Pole of the earth. The British made repeated trips to the continent between 1923-29 on the vessel, Discovery, and gathered useful environmental data.

A tiny shrimp-like organism known as Krill, swarming in huge quantities in the Southern Ocean is attracting much attraction from the point of view of doubling the world's current annual fish catch. But Krill are the major food of five species of great whales, including the endangered blue whale and humpback whale. Also some species of seals, seabirds and fish use Krill as their major food.

So far, several countries, including the U.S.A., the U.S.S.R., the Western European and Scandinavian countries, Japan and India, have carried out extensive research in the frozen continent. During the past three years, India sent three expeditions to the continent.

'Dakshin Gangotri' the research site chosen by the first Indian team in early 1982 was visited in December that year again by another team of 28 Indian Scientists. The second team worked out the logistics of establishing a manned research station and prepared an airstrip, besides carrying out scientific experiments during its 57-day stay in the continent.

A year after the second expedition, a third Indian expedition consisting of 83 members, including two women scientists, visited the continent. The team set up a two-storey building which is presently housing 12 scientists who will stay there for the coming nine months. The centrally heated building provides all basic facilities like electrical lighting, running water and spacious living accommodation. The building has two laboratories fully equipped to carry out experiments in biology and meteorology.

Concentration of threatened species

The most serious threat to plant species is habitat destruction. Plants threatened in this way are concentrated in the following ecosystem group :

Islands, especially oceanic islands in the tropics and sub-tropics ; tropical rain forests ; drylands ;

Mediterranean type ecosystems : wetlands, especially freshwater one (notably in Europe). Similarly, three most serious threats to vertebrates are habitat destruction, overexploitation, and the effects of introduced species (respectively affecting 67%, 37% and 19% of threatened vertebrate species). Concentrations of species threatened by habitat destruction closely overlap concentrations of species threatened by the effects of

introductions. Vertebrates threatened by habitat destruction are concentrated in the following ecosystem groups :

Fresh waters, especially in North America and in Africa ; islands, especially in the tropics ; tropical rain forests ; wetlands ; tropical dry or deciduous forests

More than half of the vertebrate species threatened by habitat destruction and 70% of the vertebrate species threatened by the effects of introduced species are concentrated in these areas :

Fresh waters in North America and Mexico, West and Central Africa, Southern Africa ;

Islands in Caribbean, Western Indian Ocean, South Pacific, Hawaiian Islands ;

Tropical forests in Southeast Asia, Madagascar, South America.

9 Preservation of Environment

During that last two decades concern about environmental quality has surged and become widespread. We have all become aware of environmental issues, such as pollution ; about chemicals which persist in or disappear from the environment and about their biological consequences ; water and soil pollution affecting the ecosystem ; about aerosols which float in the air and are harmful to animal and plant life ; about radiation hazards due to nuclear warfare or peaceful uses of atomic energy, which might affect our present and the future generations. Although these problems are more acute in the materially developed countries due to rapid industrialisation, the preservation of environment is also a must and a major task for the developnig countries as well. It is only a difference in the emphasis of the thrust areas—the focal themes, the relevance and priority, of one issue over the other.

The culture of a poeple, their life style, ways of ratiocination and their perception of environmental problems are products of culturally and historically rooted contexts of development. The thought and categories which go to define the notion of environment are themselves culturally specific. The destruction of indigenous cultures entails major costs for global society. Apart from the irretrievable loss of diverse tradition, philosophies and the languages. the material loss is also there. Sometimes the tribal cultures constitute a priceless and unique repository of the knowledge of the local ecosystem.

We must rely on the world's natural resources for our present and future consumption. Some of these resources are

renewable, even though limited in amount such as water, which through evaporation comes down as rain or snow; oxygen in the atmosphere of the earth; energy from sunlight; wood from growing trees and food from plants and animals. Again there are non-renewable resources which are available only in limited supply such as the fossil fuels like petroleum and coal and other minerals. Increase and preservation of these resources are necessary for the sustenance of the present and the future generations of human beings and other living organisms. We are all aware of the disasters which may be brought by nuclear explosions in any part of the world.

Bioenergy technologies are examples of 'soft energy paths'. But even a cursory study of these systems demonstrates that while they may be soft, they are not at all technologically simple or easy to operate. They carry with them their own intrinsic complexities, which must be understood and mastered in just the same way as a nuclear reactor may not be safely run, except by people who understand the underlying physics and the means of control.

An amount of 3×10^{24} J of energy from the sun arrives at the earth's surface each year. The ozone layer which today exists high up in the atmosphere is a protective umbrella from the lethal ultraviolet rays of the sun. Impacts on the atmosphere due to the accumulation of different gases such as the chlorofluoromethanes (used in refrigerators, air conditioners etc.) is potentially a serious problem. It has been estimated that if chlorofluoromethanes continue to be released at current rates, the ozone layer could be reduced by upto 15% by the middle of the next century, which in turn could impair human health and the productivity of the biosphere by allowing more harmful ultraviolet rays to reach the surface of the earth (Fig. 34).

The vast sub-continent of India, with its wide ranges of climate and topography exhibits a great diversity of natural vegetation consisting of forest types ranging from tropical wet

evergreen to arid desert, and from alpine meadows to littoral forests and tidal swamps. During the past few years the environmentalists and later the government have become aware and concerned over the rapid deterioration of the ecosystem of this sub-continent. Rapid deforestation has accelerated soil erosion leading to rising incidence of floods, causing havoc to human habitation and wild life. In India the annual cost of damage by floods ranges from \$ 140.00 million to \$ 750.00 million.

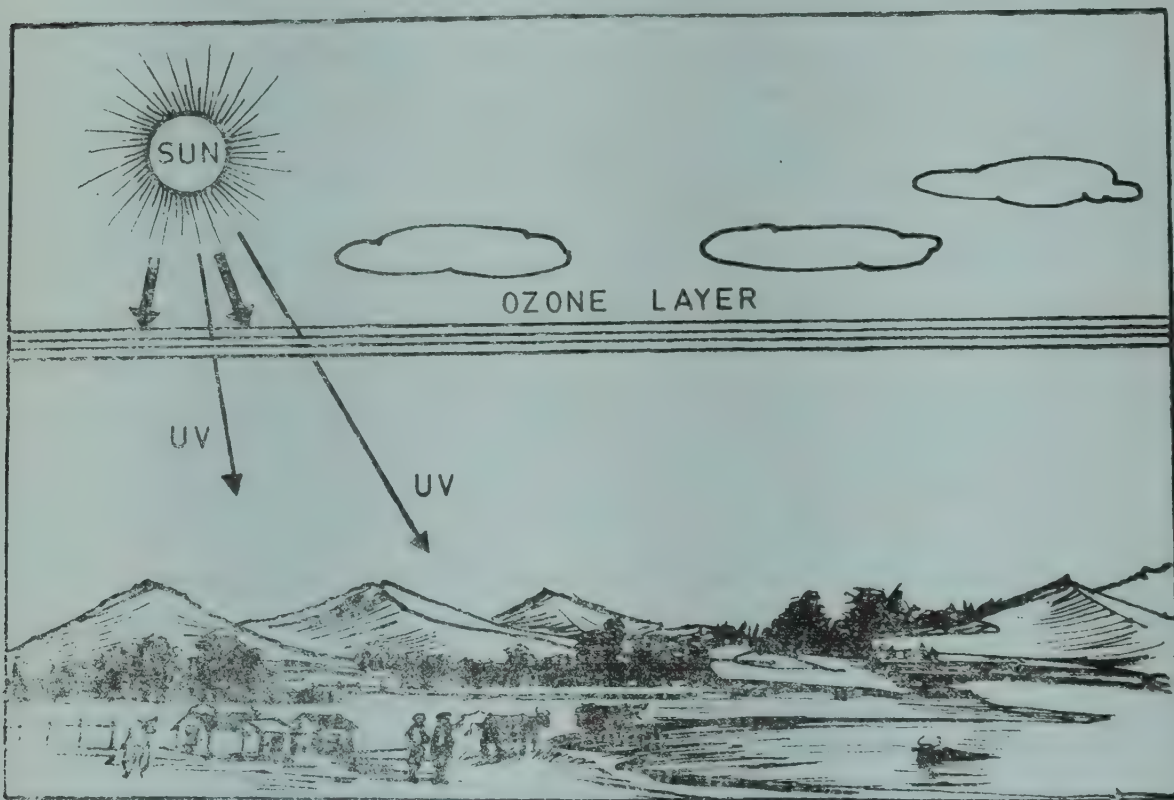


Fig. 34. If the ozone layer of the atmosphere is disturbed due to pollution then more harmful ultraviolet rays will reach the Earth.

Even, fully knowing the importance of conservation and preservation of the environment, authorities are sometimes reluctant to apply strict rules and regulations on pollution

control of the biosphere or erosion of soil or over—utilisation of resources, because the harsh pinch of economic backwardness looms at large in the background. If tree felling has to be stopped then alternative sources or means of fuel must be provided.

Planners have recently begun to incorporate an ecological perspective into rural development activities. Tackling the twin problem of rural poverty and prevention of environmental degradation requires much politico-scientific and socio-economic comprehension as well as improved planning. As priority requirement one should reserve good croplands for crops. This will reduce the pressure on ecologically fragile marginal lands which tend to degrade rapidly if exploited beyond their productive capacities. However, this requirement may again conflict with urban, industrial energy or transport policy.

Environmental Education and Conservation

School curricula should include environmental education both as an intrinsic part of other subjects (so that conservation attitudes can influence all activities) and as a separate subject (so that ecology can be taught more formally and its concepts more readily grasped). Inexpensive teaching materials (text-books, audio-visual aids, posters, pamphlets etc.) should be prepared. The materials should explain ecological concepts and the objectives of conservation, using local examples wherever possible. The effectiveness of teaching materials should be regularly evaluated. Environmental education should also be an important part of the out-of-school activities of children. Wildlife clubs should be encouraged and environmental education included in the activities of youth groups. As well as focussing on special interest groups, the several mass media (radio, television, newspapers and periodicals) should be fully used to reach the general public. Advantage should be taken of those occasions when the public comes into contact with plants and animals—in national parks and other protected areas, in zoos and botanical gardens, and in natural history museums—to explain conservation objectives and their contribution to human survival and wellbeing. In addition, special areas should be set aside for training, demonstration and education in ecology and conservation (for use by schools, universities and the general public). Such conservation education areas, besides serving their essential educational function, could also help take pressure off reserves protecting particularly fragile or unique ecosystems. Public concern

for popular animals, such as deers, should be used to foster better understanding of the ecosystems of which those animals are part. The need for environmental education is continuous because each new generation needs to learn for itself the importance of conservation. As such, individual campaigns and programmes should not be regarded as ends in themselves but as part of a long term, interactive process. It should also be recognized that any educational campaign is in competition for public attention with many others, including advertising campaign. To win and retain as much of this attention as possible, it is essential for conservation to be seen as central to human interests and aspirations.

Biotic and Abiotic Factors

The possible habitats for any living organism are limited by both biotic (living) and abiotic (nonliving) factors in the biosphere. Biotic factors include other animals, plants and microbes that may compete or otherwise interfere with essential processes. Examples of abiotic components are hydrostatic pressure, osmotic pressure, pH, light and temperature. The nonliving components also include a variety of inorganic substances such as water, carbon dioxide, oxygen and minerals, as well as organic substances.

Abiotic factors include those physical and chemical conditions in the environment that are not necessarily due to life forms. For example, a low pH can be a result of mining waste or the oxidation of sulfur by microorganisms. A high temperature may be due to volcanic activity or to microbial catabolism (Table VII).

The inter-relationships between the well known processes and several other lesser known phenomena which have been developing over a very long time, have made the entire biosphere a very complex system, whose mobile and ever changing elements balance each other out. This state of the biosphere is called "natural equilibrium," a term which we very often

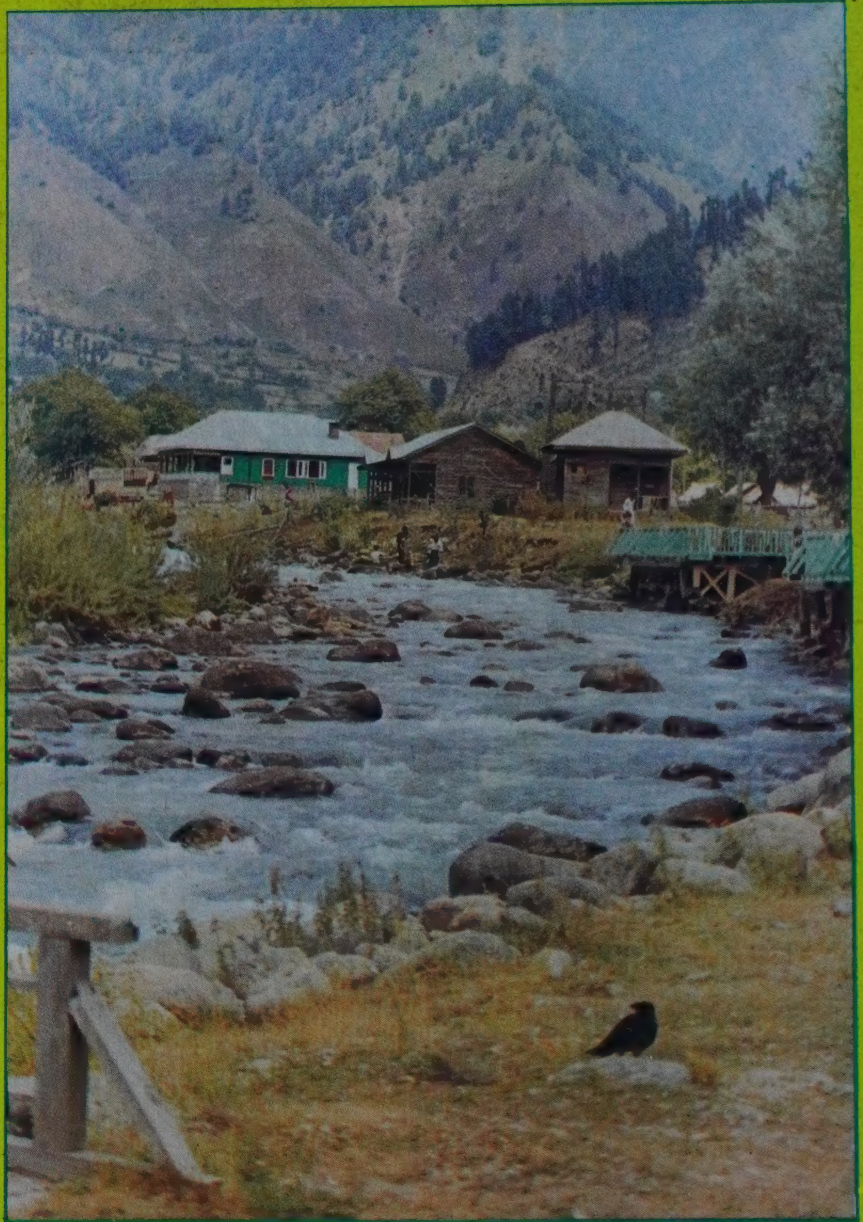
come across when dealing with problems of ecology and environmental protection. In fact our problems arise due to disturbed and upset equilibrium of the natural environment by human beings or other causes, exerting in turn pressure on the biosphere. If we try to analyse this effect we can categorise broadly the following few forms :

- (1) Changing the structure of the earth's surface through agriculture, deforestation, land development, creation of man made lakes and influencing the surface water system in other ways ;
- (2) Changing the composition of the biosphere through extraction of minerals, discharge of various substances into the atmosphere and into water bodies and through changes in moisture circulation ;
- (3) Changing the energy balance—including the heat balance—of individual areas and of our planet as a whole.

Each of these actions disturbs one or more elements of natural equilibrium'. At present, these disturbances often go far beyond the natural fluctuations of the elements of the biosphere. Some of these changes, especially pollution of the natural environment are detrimental to human life. Irreversible changes might be taking place now or in the near future, in the vast complex of natural processes. Ecologists, therefore, persist in their belief that the development of society (population growth, growth of production and consumption) will inevitably have negative effects on humans. These consequences in combination with the depletion of resources amount to what is termed as an ecological crisis.

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